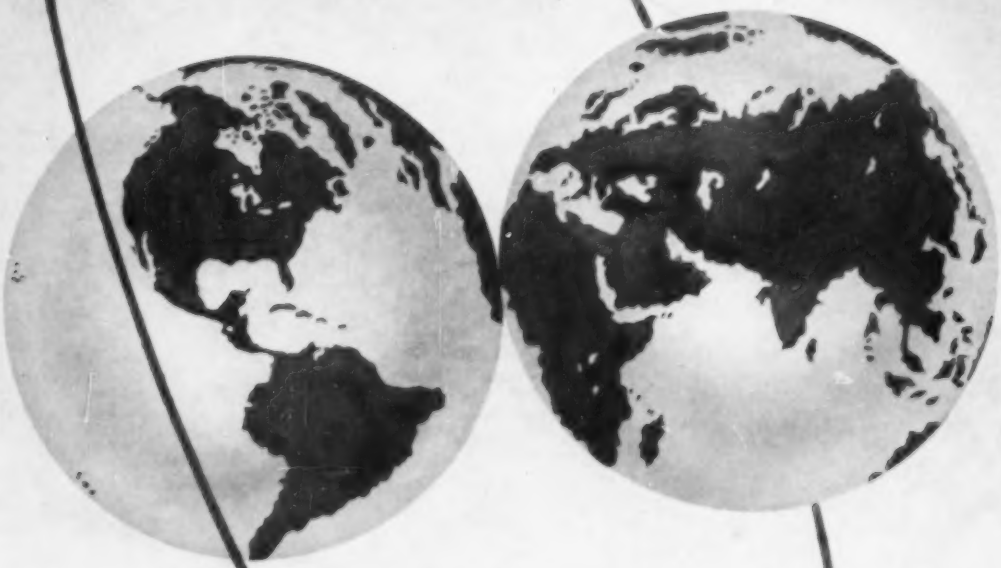
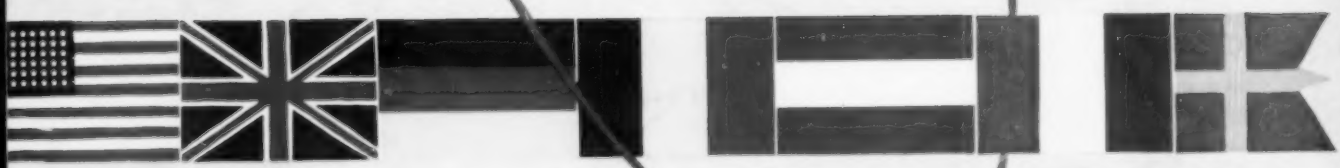
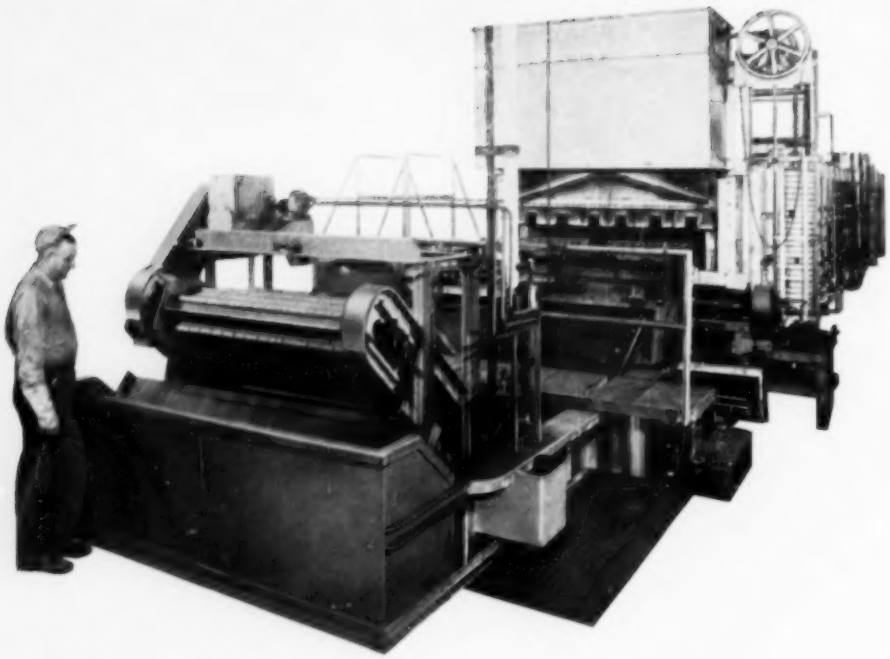
Metal Progress

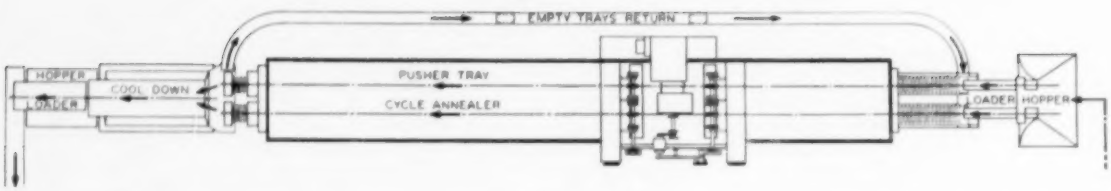




January 1956

F.E. Craig





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Metal Progress

Volume 69, No. 1

January . . 1956

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Cover by FLOYD E. CRAIG

Annual International Review of Metallurgy

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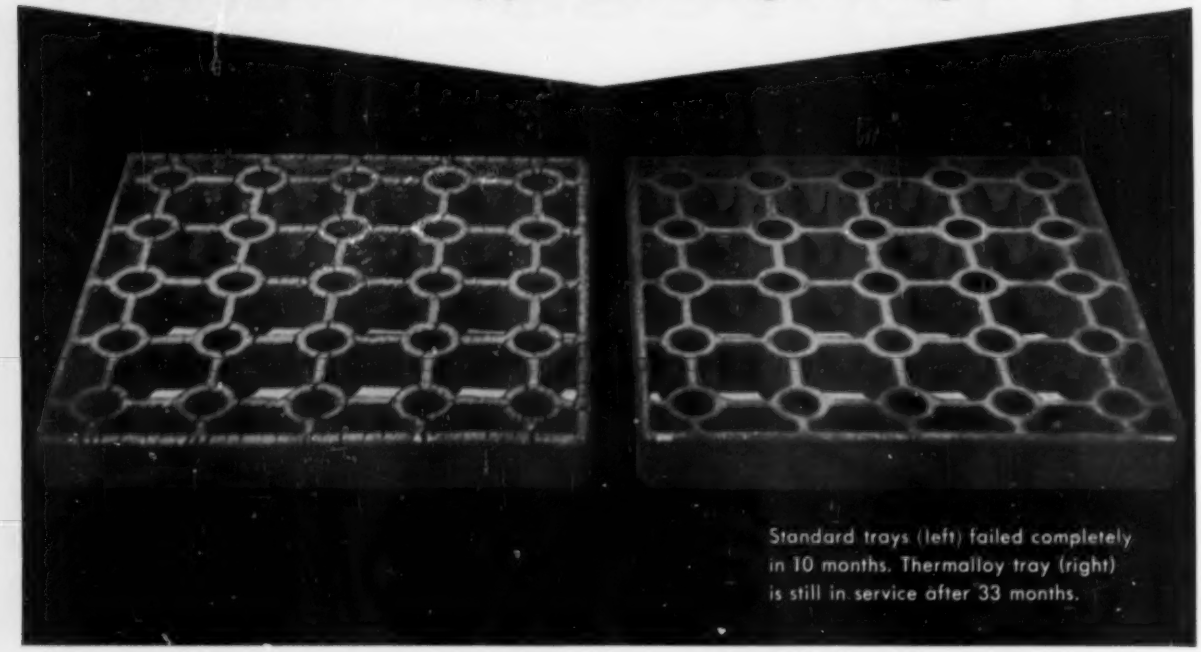

Standard trays (left) failed completely in 10 months. Thermalloy tray (right) is still in service after 33 months.

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As I was saying...

THE MOST important thing I have to write for this month's column is "A happy New Year to yours and you, and may the coming year bring you all the joy and happiness it is possible for anyone to enjoy."

I remember a childhood custom, in which on the first day of the year the person who said "New Year's gift" when meeting another was supposed to have a hundred-to-one chance to receive a gift from the person he had challenged.

So here is a "New Year's gift" for you. I am most happy to bring tidings about A.S.M.'s future home.

As you are aware, the No. 1 project in "The A.S.M. of Tomorrow" — the building of a new headquarters — has been approved by the Board of Trustees. Consequently, the Board has given serious and conscientious consideration to its geographical location. It was finally decided that the new A.S.M. headquarters should be in Cleveland. Then the problem was whether it should be located in downtown Cleveland or in the suburbs. It has taken time to review the pros and cons of an urban vs. a suburban site, and extended study was necessary not only of present needs but also the possible needs for 5, 10, 20 and even 50 years into the future.

The Board consulted with the very best authorities, and after due deliberation voted unanimously to select a suburb as offering the best opportunity for the greatest service to the present members and offering unlimited possibilities for future development along the lines outlined in "The A.S.M. of Tomorrow".

The next important decision to come before the Board will be the selection of a definite site on Cleveland's periphery. A committee is now at work, through important real estate sources and by means of advertising in the public press, to secure offers of desirable sites of 50 to 100 acres—sites that may be protected from industrial encroachment and that will provide desirable surroundings for an educational institution and activities for many years to come. I will let you know as soon as a definite location has been determined. Even at that, the builders and architects with whom we consulted indicated it will take 18 to 24 months to finish details and to complete a building for occupancy.

Item No. 2 on "The A.S.M. of Tomorrow", Metals Engineering Institute, a division of the A.S.M., is making commendable progress toward the possibility that at least four or five of the 41 lesson courses will be completed and published so they may be made available to members of the Society by early spring. These courses will be confined to use by A.S.M. members at first, on the basis that promotion to others would not be justified when only five of the 41 courses are available for immediate enrollment.

Each course has 15 lessons. We have already received, and are receiving almost daily, lessons from the various courses as they are completed by the authors. Many members of the Society are cooperating by reviewing the chapters, adding illustrations, comments and suggestions so that when the last chapters are received all the courses will be almost ready to shoot.

Not only will these completed courses be available for individual instruction by way of correspondence, but also will be available for in-plant training. Instructors for such classes will either be furnished by the plant or will be secured by A.S.M.

So, starting with the New Year, it is certainly fine to realize that your Board of Trustees are making "no little plans" and that they have confidence and vision so that with your help "The A.S.M. of Tomorrow" will progress onward and upward and will become an enduring monument to your helpful cooperation as well as a portent for many happy years to come.

Cordially yours,

Bill

W. H. EISENMAN, *Secretary*
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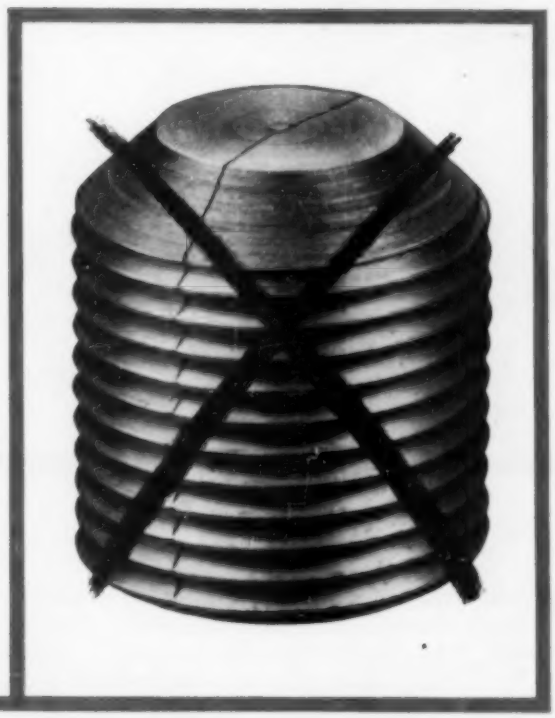

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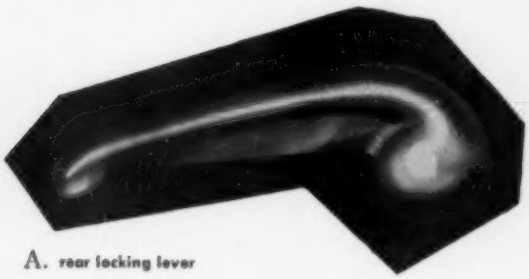
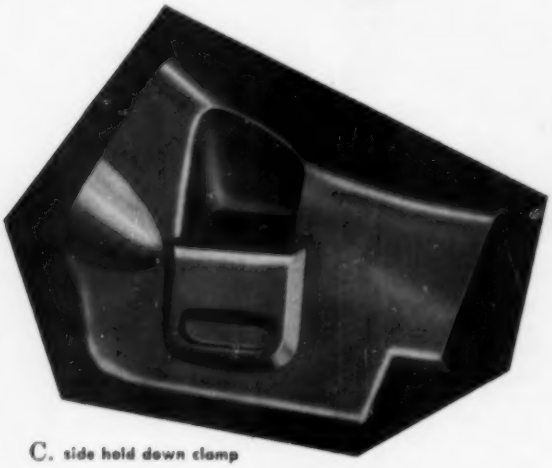


A. rear locking lever

B. rear hold down clamp



C. side hold down clamp

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Copper Base Alloys in Rod Form
Engineering Manual FM-3010 ☐

METALS AND ALLOYS REVIEW

by FRANK M. LEVY, Director of Research

The other day one of our sales engineers stopped in to discuss gear applications and the subject got around to the amount of zinc permissable in gear and bearing alloys. Engineering books state that zinc is not desirable in bearing alloys. While this statement is true as regarding the commonly used copper-tin and copper-tin-lead alloys, it does not necessarily apply to other types of alloys. The 600 series bearing alloys, in which I am keenly interested, depend upon a high zinc content along with several other metal constituents to provide them with their fine bearing properties.

My explanation to our sales engineer was somewhat as follows: The question as to whether or not zinc is detrimental in a bearing alloy depends upon the remaining constituents in the alloy. A comparatively small amount of zinc is detrimental in a phosphor bronze alloy containing 80% copper, 10% tin and 10% lead. A zinc content of 4% is permissible in a bearing alloy containing 88% copper, 4% tin and 4% lead when used in an application not subject to heavy loads. In these alloys the tin combines with some of the copper to form a hard copper-tin constituent which is distributed through the soft copper matrix, or mat of copper. The higher the percentage of tin present, the greater the quantity of hard copper-tin constituent formed. Zinc also combines with copper increasing the hardness of the matrix. Therefore, when zinc is present along with a high tin content, the matrix becomes too hard and is "out of balance" resulting in poorer bearing qualities.

In the 600 series, copper, silicon, manganese, etc., are present with zinc. There is sufficient manganese present to combine with the silicon to form a purple manganese silicide which is embedded in the copper-zinc matrix. *Since the manganese-silicide constituent has a much higher micro hardness than the copper-tin constituent in phosphor bronze, the matrix of the 600 series alloys can have a higher hardness without impairing the bearing properties. In this instance, zinc is not detrimental but desirable because it produces an alloy with a high Brinell hardness which resists pounding and distortion.*

Like many engineers, we, too, were skeptical of the bearing properties of the first 600 alloy developed. A manufacturer of worm driven truck transmissions was having difficulty with the failure of chill cast high tin bronze gears in busses used in the hilly section of Los Angeles and Pittsburgh, and solved his problem by using gears made from 600 metal.

Since that time, we have had over a hundred successful applications on difficult bearing problems where cast bearing bronzes have failed. An interesting observation is that once a customer uses 600 alloys, he not only finds other applications, but continues to use it over a long period of years. Our original customers are still on our books.

In conclusion, we agree that zinc is detrimental to the bearing properties of the phosphor bronze type of alloys, but is of benefit to the 600 series alloys, *as it makes a harder matrix*, permitting the alloy to resist pounding action better than the softer phosphor bronze alloys.

I've just about run out of space for this time but we'll have another subject for discussion later. If you have any problems or questions about non-ferrous alloys, just write me here at Mueller Brass Co. and we'll see what we can do.

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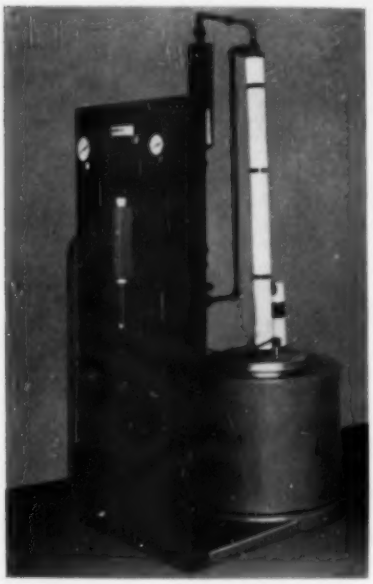
☐ **IMPACT TESTING MACHINES** — A combination machine for making Izod, Charpy or tension tests. Can also be furnished as a single purpose machine. Capacities up to 220 foot-pounds.

☐ **TESTING MACHINES GUIDE** — An 8-page Bulletin covering the line of Riehle Testing Machines and Instruments.

Engineering Digest of New Products . . .

Ammonia Dissociator

Connecticut Gas Atmospheres has announced a retortless ammonia dissociator. All dissociation takes place in a tightly wound Inconel coil filled

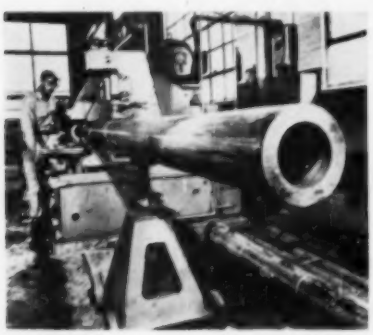


with catalytic balls which assures intimate contact between ammonia and catalyst. Two models in capacities of 150 and 300 c.f.h. are standard. Operating temperature is 1750° F.

For further information circle No. 1 on literature request card, p. 32-B.

Continuous Casting

Continuous-cast bearing bronze is now available in 44 new, larger sizes from 5 to 9 in. in diameter up to 12



ft. long in many foundry alloys and a variety of shapes, as announced by the Continuous-Cast Products Dept., American Smelting and Refining Co. Up to now centrifugal castings ranged from ½ to 5 in. in diameter. Design modifications in melting, casting, driving, sawing and handling equipment were necessary to make the larger castings. The basic process remains unchanged. Molten metal supplied by an auxiliary melting furnace is maintained at a proper temperature in the casting crucible. Solidification of the rod or tube takes place in a self-lubricating, water-cooled graphite die. Driving wheels, mounted directly beneath, withdraw the solidified product continuously at controlled speed. A traveling saw, mounted below the driving rolls, is engaged at proper intervals to cut uniform lengths.

For further information circle No. 2 on literature request card, p. 32-B.

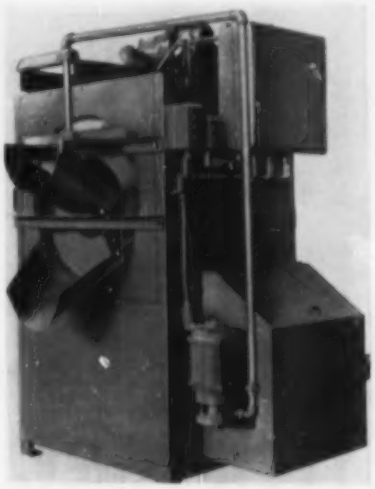
High-Temperature Thermocouples

Thermo Electric Co. has announced a new thermocouple with platinum—30% rhodium-platinum — 6% rhodium calibration, capable of measuring temperatures up to 1800° C. This extends the practical range for industrial temperature measurement beyond the limits of the platinum—10% rhodium-platinum thermocouple and neither sensitivity nor corrosion resistance are sacrificed.

For further information circle No. 3 on literature request card, p. 32-B.

Bulk Washing

Small parts can now be high-pressure spray-washed in bulk by means of a new small rotary-drum batch-type machine announced by the Alvey-Ferguson Co. Parts batches are introduced into the machine through the upper chute. The new machine utilizes a drum with helical spiral to tumble parts gently and expose all surfaces thoroughly to the high-pressure fan-shaped spray nozzles inside the drum. The drum, perforated to permit draining of the solution, oil, chips and impurities, retains only the clean, thoroughly-washed parts. On completion of the cleaning cycle, the drum counter-revolves, automatically discharging the clean parts into a tote box or other suitable container by

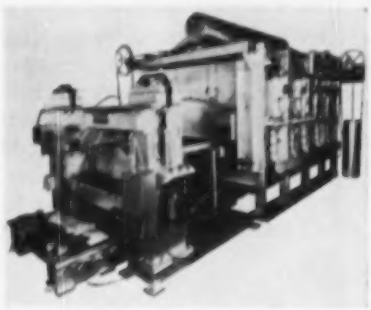


means of the lower chute. The washing, pumping, drum-reversing cycle can be either manual or automatic.

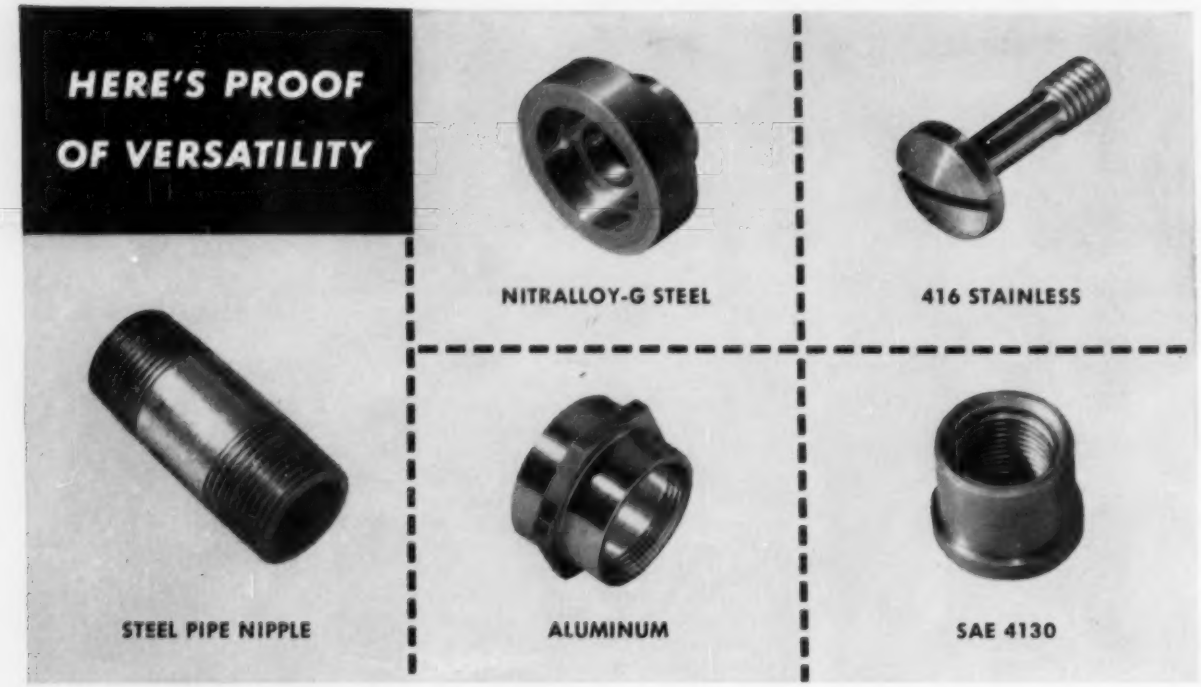
For further information circle No. 4 on literature request card, p. 32-B.

Forge Furnace

An automatic work handling system for a forging furnace has been announced by Hautau Engineering Co. A special feature is a walking beam loader which moves with varying velocity so that the part is lifted



slowly, then quickly moved to a new position where it is slowly deposited. A stack of incoming parts are deposited on two rails. The stack is automatically shuttled to an elevator which rises intermittently to maintain



SUN DEVELOPS VERSATILE NEW CUTTING OIL FOR SCREW MACHINES AND JOB SHOPS

New cutting oil, Sunicut 5534, is moderately priced... gives excellent machining results on wide range of steels

New Sunicut 5534 is a non-emulsifying, transparent cutting oil specially compounded to give above-average machining results to operators who want a single oil to machine a large variety of ferrous metals.

Tests have proved that new Sunicut 5534 meets this demand for an all-purpose cutting oil. It is ideal for general screw machine and turret lathe work. It is also excellent for tapping, drilling, threading, and light stamping operations. In addition, new Sunicut 5534 can be used on many special machining jobs, both high and low speed, with metals ranging from B1112 to 4130 as well as free-machining stainless steels.

For complete information about new Sunicut 5534 and how it can help you reduce your oil inventories... lower your production costs... see your Sun representative. Or write SUN OIL COMPANY, Phila. 3, Pa., Dept. MP-1.

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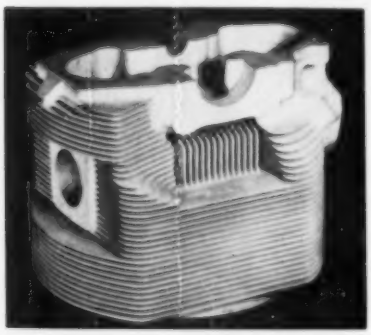
a constant stack height. Two cut-off bars separate the top blank from the stack and slide it onto the furnace's stationary rails. The walking beam picks the blank up from here and carries it step by step through the furnace. On the output end of the furnace an unloading mechanism which derives its motion from the walking beam moves the part out of the furnace through a distance of 40 in. to a pressing operation in only 1 sec. Ten piloted nozzle mixing burners maintain the furnace at 2400° F. The light weight insulating firebrick lining minimizes the time required to bring the furnace to full temperature.

For further information circle No. 5 on literature request card, p. 32-B.

Alloying Aluminum

A titanium-aluminum hardener for aluminum castings has been announced by Shieldalloy Corp. Used as a 5% alloy, its effect is to refine the grain structure of aluminum sand castings, thus resulting in improved physical properties of the final product, including increased tensile strength and ductility. Castability of aluminum alloys is improved, fluidity



and resistance to pressure are increased. The addition of the intermediate alloy also prevents hot cracking. The 5% titanium material is recommended because it dissolves easily and rapidly in molten aluminum avoiding the necessity for overheating the metal. The amount to be added to the base alloy should be adjusted so that the molten metal will contain between 0.15 to 0.20% titanium.

For further information circle No. 6 on literature request card, p. 32-B.

Serial Marker

A device for photographing a four-digit number on any plate or film before it is developed has been announced by Spex Industries, Inc. The number is tucked away in a corner and does not interfere with spectrograms, X-ray pictures or other images on the negative. For reference purposes, the number is photographed

then a button is depressed which advances the counter to the next number. Resetting is accomplished by turning a knob. The instrument operates on 115 v., a.c.

For further information circle No. 7 on literature request card, p. 32-B.

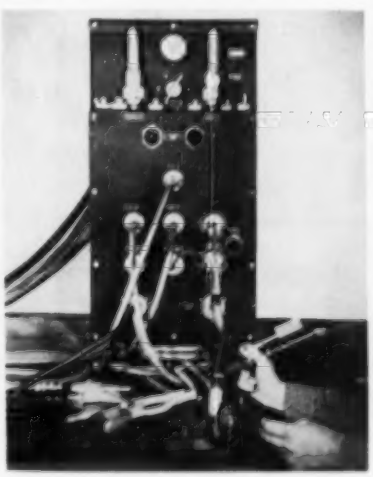
Billet Heating

Magnethermic Corp. has announced a 60-cycle induction billet heating installation at Kaiser Aluminum & Chemical Corp.'s Halethorpe, Md., plant. The installation of six 400 kw. induction heaters will preheat aluminum billets for two 8000 ton extrusion presses. Billet sizes range up to 26 in. in diameter and 65 in. long. Total capacity is in excess of 12 tons per hour. Billets are automatically loaded into the heaters from in-feed conveyors and heated billets are automatically loaded into the press.

For further information circle No. 8 on literature request card, p. 32-B.

Welding Control Unit

A newly developed accessory control unit for inert-gas, shielded-arc welds using conventional welding machines has been announced by Flexweld Mfg. Co. It provides automatic



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A powdered product to produce a bright clear conversion coating on zinc and cadmium.

LUSTER-ON ACTIVATOR

Designed for preparing a zinc alloy die casting prior to treatment in our Luster-On acid baths. Also serves as a mild cleaner. However, heavy soil must be handled by a pre-cleaner.

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L-18

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Forged-in pockets provide tougher, stronger dies

This 35,000-pound die block, made of Finkl FX-T3 steel, has a forged-in pocket 12″x29″x34″. In addition to the improved physical properties, the pocket forging increases the saving in machining time. There are many ways, such as this, that Finkl engineers can help you when planning die block or forging requirements.

When you next consider hot work tooling, die blocks or forgings, consider Finkl for the best. The quality of Finkl Hot Work Die Steels is the finest available and costs you less in the long run. Finkl die blocks will make a lasting impression with "impressions that last." Our engineers will gladly offer the advantage of their knowledge and our experience. There is no obligation.

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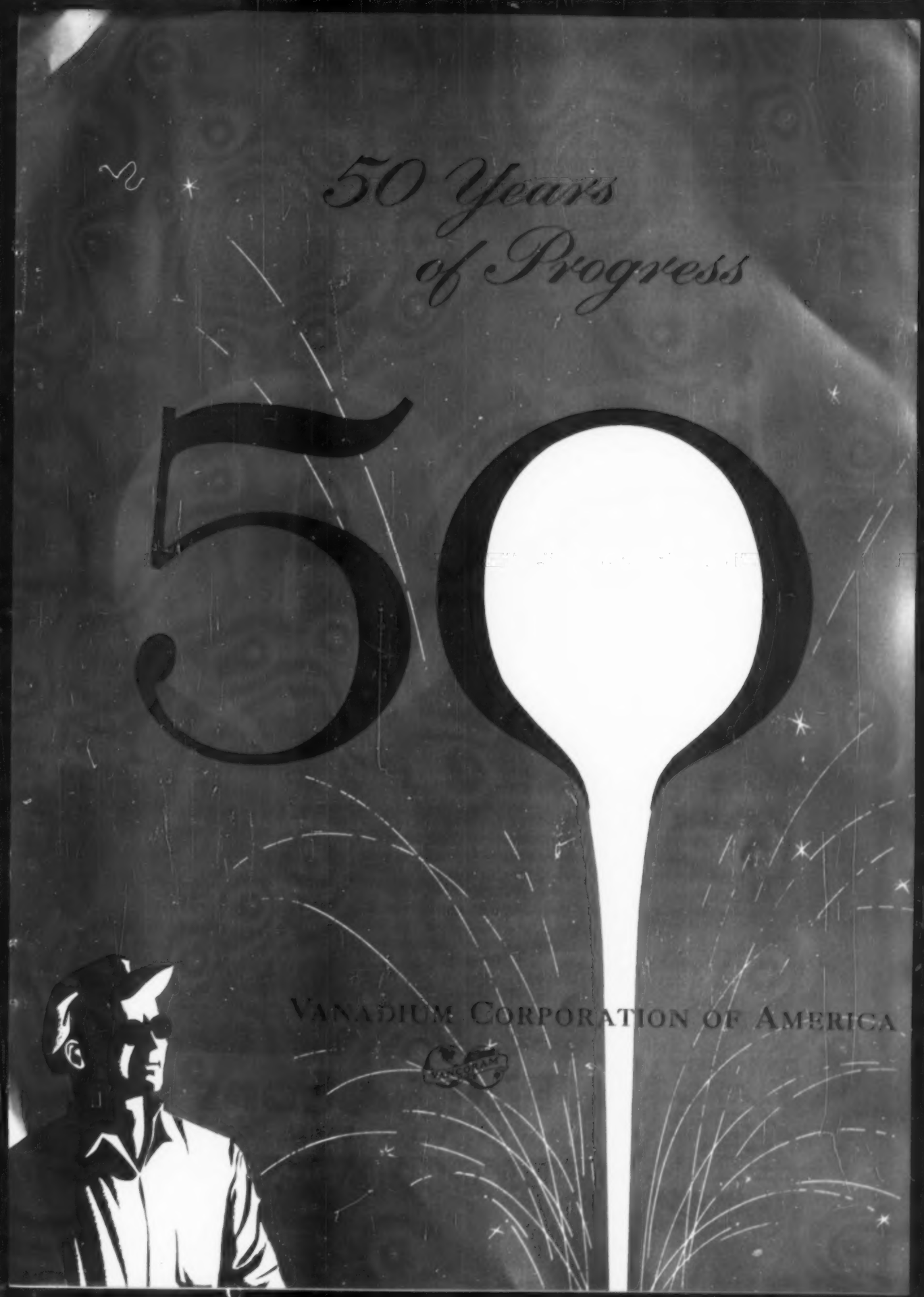
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of Progress
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Since the discovery of Mina Ragra fifty years ago – the world's richest vanadium mine – we have been absorbed in one of the most fascinating occupations in industry: the development and production of ferro alloys, metals and chemicals. Working closely with the metals and chemical industries and other progress builders, we contributed to many of the engineering achievements of our day: jets . . . automobiles . . . machine tools . . . mining, construction and agricultural machinery and scores of other products that range from sleek, swift streamliners to tough, heavy-duty synthetic fibers.

We were privileged to take part in these and numerous other developments in the past half century, for their success depended in part on the ferro alloys, metals and chemicals which VCA helped pioneer and produce. Now . . . on the occasion of our fifty years of service to the Metals Industry, we look ahead to . . .

THE NEXT FIFTY YEARS . . .

To assure a steady, continuous supply of raw materials, we have expanded our mining operations. We have enlarged and modernized our milling and smelting operations. We have recently built two new plants. And plans are now under way for the construction of a third, designed to meet the ever-increasing need for Vancoram ferro alloys. We have built a new Research Center – one of the finest of its kind to be found anywhere – for the important work of developing new and improved Vancoram products and assisting customers in the solution of their alloy problems.

Looking ahead to the next fifty years, there will be a need to develop special alloys, metals and chemicals to meet the requirements of the jet and atomic age. Our Research Center is already at work on these and other important problems in every phase of our technology. All this to achieve a goal: to serve the Metals Industry better than we have ever served it before.

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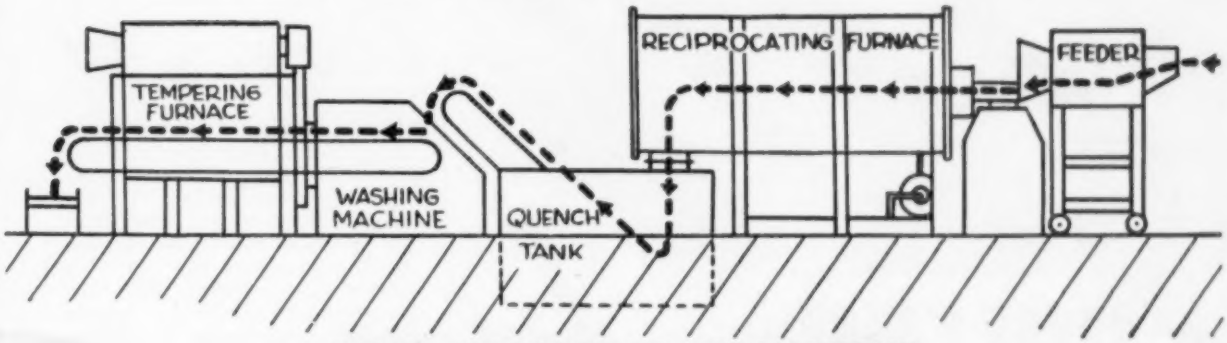
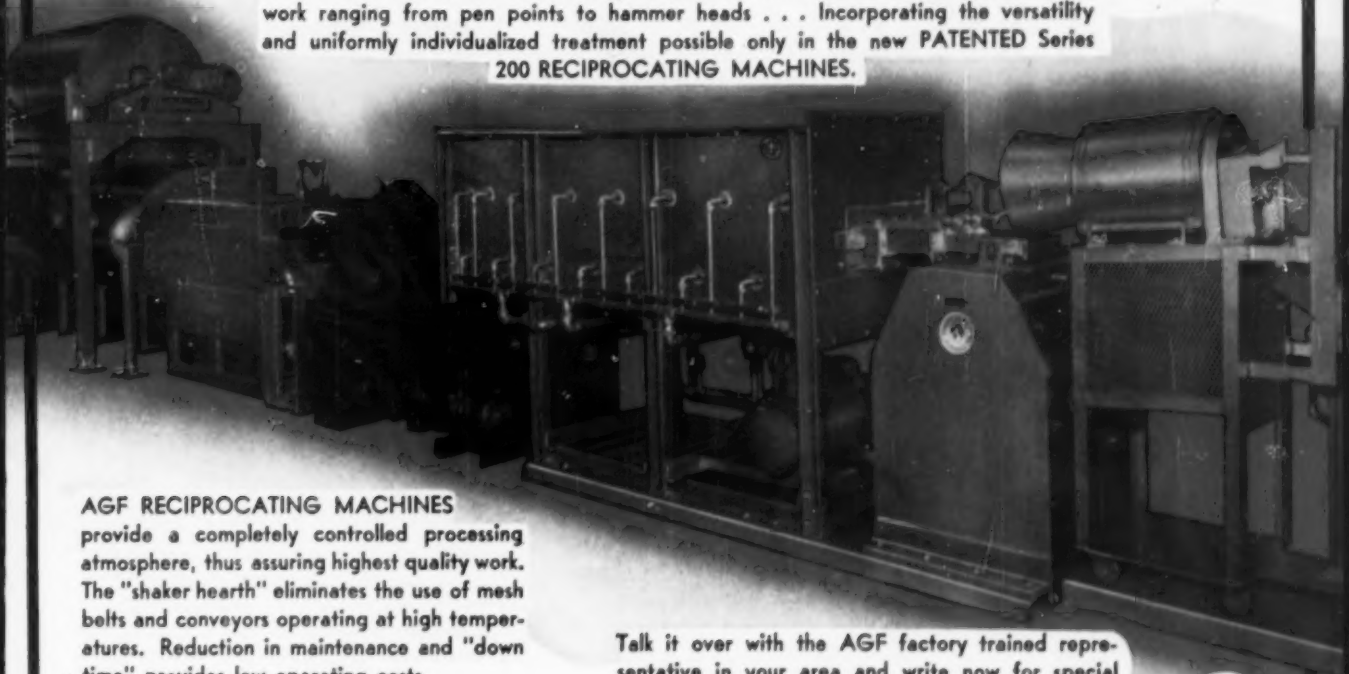


"YOUR APPROACH TO AUTOMATION"

COMPLETE Installations to handle your product from 100 to 800 lbs. per hour of work ranging from pen points to hammer heads . . . Incorporating the versatility and uniformly individualized treatment possible only in the new PATENTED Series 200 RECIPROCATING MACHINES.



AGF RECIPROCATING MACHINES provide a completely controlled processing atmosphere, thus assuring highest quality work. The "shaker hearth" eliminates the use of mesh belts and conveyors operating at high temperatures. Reduction in maintenance and "down time" provides low operating costs.

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Thus you will gain access to the special advantages VULCAN Tool Steels offer—to help you produce your finest tools and dies.

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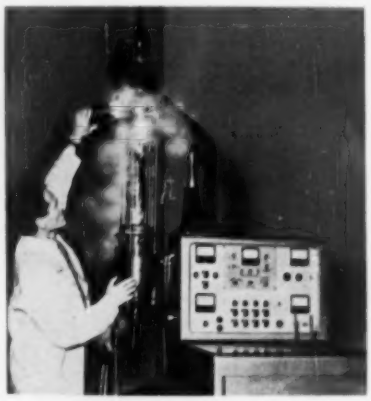
Offices in Pittsburgh, New York, Cambridge, Baltimore, Birmingham, Detroit, Lansing, Chicago, Milwaukee, St. Louis.

control of torch and back-up gas, torch and fixture cooling water, high-frequency starting spark and welding current. It also features welding current polarity indicator, back-up and torch-gas flowmeters receptacles for conventional arc welding, air pressure regulator with air supply fittings, 110-v. auxiliary power receptacles.

For further information circle No. 9 on literature request card, p. 32-B.

Refrigerator

A new-type refrigerator that will maintain lower temperatures than any previous apparatus has been developed at Arthur D. Little, Inc. The temperatures produced in this machine come to within a fraction of a degree of absolute zero (−459.6° F.). The refrigerating system is based on a cyclic principle of magnetic cooling. There are no moving parts or flowing fluids in this cooling system. It uses a plastic capsule 3 in. long, containing



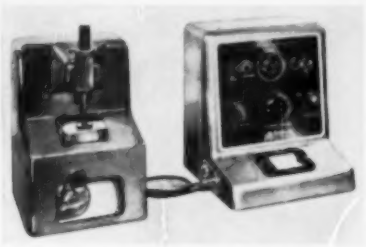
a special chemical salt as the refrigerant. Operation of the refrigerator is controlled entirely by external magnetic fields. Magnetic cooling utilizes the fact that certain materials will warm up when magnetized and cool when demagnetized, and has been used for several years in a few low temperature laboratories for achieving extremely low temperatures. This apparatus has been able both to produce these extreme low temperatures and to maintain them for long periods of time.

For further information circle No. 10 on literature request card, p. 32-B.

Electrolytic Polisher

A new electrolytic polishing instrument for metallographic laboratories has been announced by Buehler, Ltd. The new unit has more power than preceding models and includes the power pack, a self-contained rectifier with an output of 5 amp. d.c. and a positive variable output control in both a high range for polishing and

a low range for etching and low current density polishing. An automatic presetting timer provides for polishing cycles. A variable transformer controls the speed of the polishing cell's universal pump motor. The separate polishing cell contains a

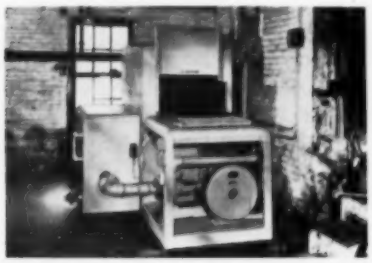


pump mechanism within the electrolyte tank, and the anode contact plunger to hold specimen positioned over the cathode opening in the tank. The unit includes three different size washer orifices, 5/16, ½, ⅝ in. in diameter.

For further information circle No. 11 on literature request card, p. 32-B.

Parts Washing

A spray-type washing machine for the heat treating department, manufactured in standard sizes to fit the 24 x 36 x 15 in. carbonitriding furnace



trays, has been announced by Waukee Engineering Co. It is also available in 24 x 48 x 18 in. size. The gas-fired model is heated by an immersion tube. Spray nozzles above and below the work are supplied by a 240 gal. per min. pump driven by 2 hp. motor. The unit is supplied with magnetic starters, automatic temperature control, pilot safety device and timer. The washer can be supplied electrically or steam heated also.

For further information circle No. 12 on literature request card, p. 32-B.

Fatigue Testing

Ivy Co. has announced a new fatigue testing machine with total force capacity of 12,000 lb., designed for multi-range fatigue testing. The multi-range feature provides two test stations—one for high force and the other for high amplitude operation.

This is achieved by using a torque bar instead of coiled springs, which also permits use of the machine with heavy test pieces and fixtures. At the high force station, the maximum load is 12,000 lb. and the total available amplitude is ±⅝ in. The high amplitude station provides for ±¾ in. amplitude (or 1½ in. full travel) and a maximum force of 6000 lb. Settings for both static and dynamic forces are calibrated directly in pounds. Static force is maintained constant by an electronic controller.

For further information circle No. 13 on literature request card, p. 32-B.

Abrasive Wheels

A special web backing of spiral wound rayon auto tire cord imparting extra strength and safety to high speed abrasive wheels has been incorporated in the new Simex red wheels according to Simonds Abrasive Co. These wheels are light-weight, rigid, reinforced resinoid bonded abrasive wheels for use on portable disk and right-angle portable grinders. They are made in depressed center or raised hub shape in 7 and 9 in. diameters by 3/16 and ¼ in. thicknesses. Their field of application is

for rough production grinding especially for grinding welds, removing flash and bead, cleaning up rough ragged surfaces and edges and for all types of stainless steel.

For further information circle No. 14 on literature request card, p. 32-B.

Cut-Off Machine

Automation is available to any degree with the Bridgeport abrasive cut-off machine, according to Lobdell Div. An air cylinder and hydro-check actuate the head; vise operates by

Stepless temperature Control

NOW! TUBELESS, MULTI-LOAD

Improved Model JS Series GARDSMAN Stepless Controllers by WEST. One instrument handles a range of wattage requirements.

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You can cut production time and increase output when you fabricate from pre-painted aluminum. Colorweld Coil, roller-enameled aluminum, retains its original color perfection throughout most fabrication stresses and production operations. Colorweld's baked-on enamel finish permits bending, forming, slitting, stamping and most drawing operations without scratching or peeling. By a special process, including careful Alodizing, the colors literally are welded to the metal for a lasting finish.

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To add sales appeal to your products at substantially reduced production costs, fabricate your products from Colorweld Coil. We shall be glad to send you additional information, without obligation. Write to us today.

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SOUTHERN STATES IRON ROOFING COMPANY
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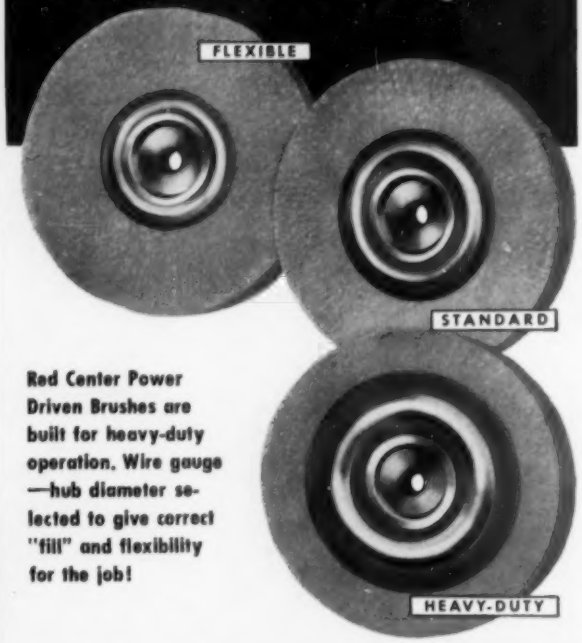
New Pittsburgh Red Center construction assures faster, better, easier brushing!



Red Center Power Driven Brushes are built for heavy-duty operation. Wire gauge —hub diameter selected to give correct "fill" and flexibility for the job!

Here's how Red Center Brushes work

Even distribution of wire is made around the hub. Naturally the hub size determines amount of wire used. The larger the diameter the more wire used and more rigidity obtained. Three diameter sizes: Flexible (Long Trim), Standard (Medium Trim), Heavy-Duty (Short Trim), all built with gauge wire you specify.

What does Red Center mean to you

Pittsburgh Red Center means precision brushing made by uniform "fill" of a specific gauge, quality wire—mounted in a specially designed hub to give exact brushing surface and strength required. With all these features you're assured of longer brush life, faster cutting, finer finishing.

GET THE FACTS: for information regarding your specific brushing problems, write: PITTSBURGH PLATE GLASS CO., *Brush Div.*, Dept. Y-1, 3221 Frederick Ave., Baltimore 29, Maryland.

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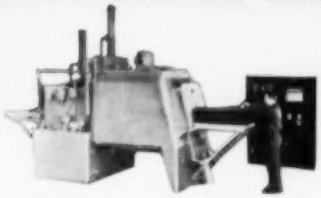
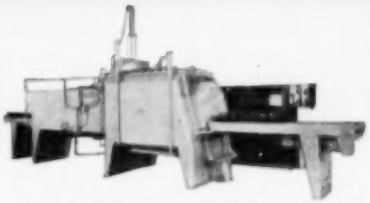
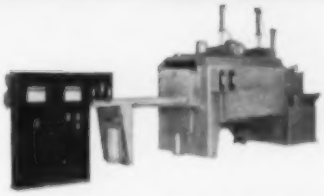


This Ipsen T-400 Automatic Atmosphere-Controlled Unit is the most versatile of all units.

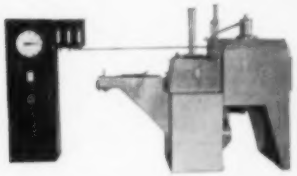


TFC Units for automatic, controlled-atmosphere heating and forced cooling under atmosphere.

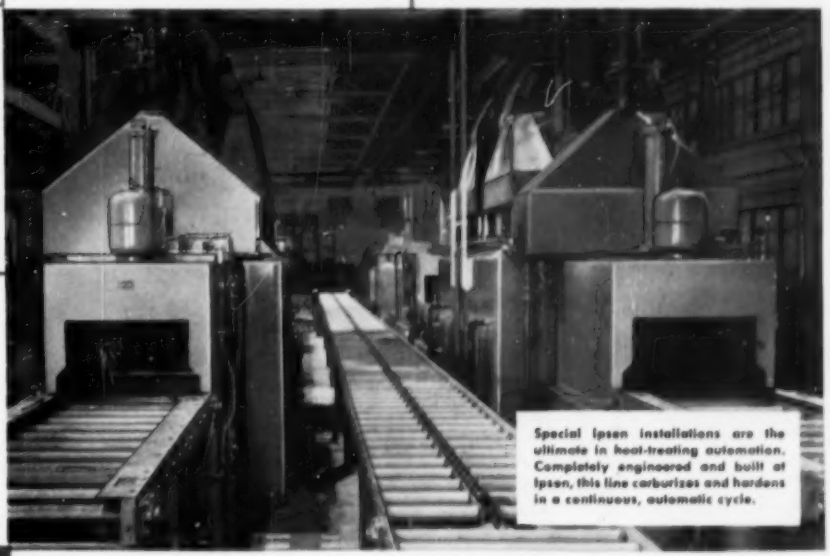


Standard production units with independent heating zones, with capacities up to 3000 pounds per hour.

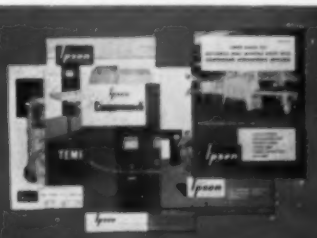
Ipsen auxiliary equipment . . . gas and electric Generators; Dewtronik and Carbotronik Controllers.



The RT-25-E permits controlled-atmosphere heat treating in the laboratory or tool room.



Special Ipsen installations are the ultimate in heat-treating automation. Completely engineered and built at Ipsen, this line carburizes and hardens in a continuous, automatic cycle.



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AUTOMATIC Ipsen HEAT TREATING UNITS

OR CONTACT ANY OF THESE SALES OFFICES

Whatever your heat-treating requirement may be, now there is an Ipsen Controlled Atmosphere Unit to meet it . . . standard units from 25 to 3000 lbs./hr., or special installations engineered to individual production needs. Experienced metallurgists will analyze and recommend correct procedures. Why not contact an Ipsen sales engineer . . . today!

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Hartford, Conn.	Burbank, Calif.	Denver, Colo.
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Detroit, Mich.	Houston, Texas	Amsterdam, Holland

Norton materials for high temperature processing

Temperature range of Norton electric furnace materials

C° Melting Point	Temperature of Electric Arc Furnace 4000° C–7230° F	F° Melting Point
3540	ZIRCONIUM CARBIDE ZrC	6400
3300	FUSED THORIA ThO_2	5970
3140	TITANIUM CARBIDE TiC	5680
3060	ZIRCONIUM BORIDE† ZrB_2	5540
3000	BORON NITRIDE BN	5430
2900	TITANIUM BORIDE† TiB_2	5250
2700	FUSED ZIRCONIA ZrO_2	4900
2620	MAGNORITE* Fused Magnesia MgO	4750
2450	NORBIDE* Boron Carbide B_4C	4440
2300	CRYSTOLON* Silicon Carbide SiC	4170
2000	38 ALUNDUM* Aluminum Oxide Al_2O_3	3630
1900	REGULAR ALUNDUM Aluminum Oxide Al_2O_3	3450

All True Color Temperatures

†Experimental Materials

*Trade-Marks Reg. U.S. Pat. Off. and Foreign Countries

Are You Stymied by a "High Temperature Barrier?"

Are you concerned with industrial processing involving temperatures ranging upwards to 4000° C? If so, Norton Company has developed and is continually improving materials — produced and purified in electric arc and high temperature resistance furnaces — which may help you solve difficult technical problems. Norton Company supplies these materials in crude, processed or fabricated form — and will work with you in engineering them to your requirements. For further information, write to NORTON COMPANY, Refractories Division, 320 New Bond Street, Worcester 6, Mass.

Making better products . . . to make other products better

NORTON
REFRACTORIES

Engineered . . . Rx . . . Prescribed

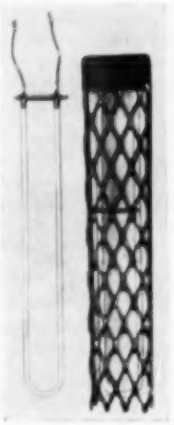
air cylinder; feeding mechanism which grips material to be cut, moves it into position; and a series of microswitches tie above operations into a cycle which repeats automatically. Other features

include stainless steel spindle with grease sealed bearings, coolant applied equally to both sides of cut, vise holds both ends of piece being cut and a swivel head assures accurate angle for cutting.

For further information circle No. 15 on literature request card, p. 32-B.

Immersion Heater

The Glo-Quartz Electric Heater Co. has announced a line of new "U" type quartz immersion heaters. These heaters were designed for heating acid electroplating and pickling solutions. They consist of two interchangeable components —the "U" shaped quartz heating element and the combined junction box and guard assembly. The resistance heating element is mounted inside the "U" shaped quartz tube and the coil is supported with a special heat-conducting powder. Sealing locks out acid fumes.



For further information circle No. 16 on literature request card, p. 32-B.

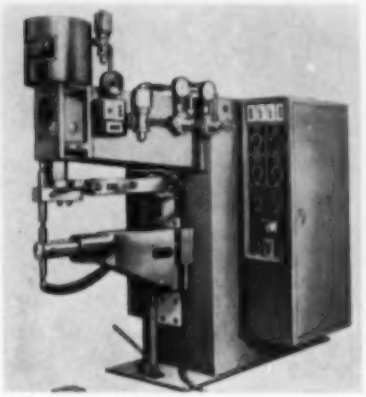
Casting Repair

An aluminum putty which consists of approximately 80% aluminum and 20% plastic and which is used for filling very large and small holes in aluminum and steel castings, to cover holes which have been drilled incorrectly and to build up worn sections has been announced by Chemical Development Corp. Devcon F will adhere to aluminum, steel, bronze, brass and cast iron. It will bond to flat surface and can be machined. A special hardening agent is supplied with every Devcon container.

For further information circle No. 17 on literature request card, p. 32-B.

Spot Welder

Sciaky Bros. has announced the new design of spot welder. It is available in 100 kva. at 50% duty cycle and can be supplied with either 36, 48, or 54 in. throat depth and electrode force up to 4300 lb. at 80 psi. line pressure. It will weld a wide



range of low carbon steel, austenitic steels, aluminum and magnesium alloys, air hardenable steels and stainless steel.

For further information circle No. 18 on literature request card, p. 32-B.

Recorders

A new line of strip-chart recorders featuring a plastic throw-away inkwell has been announced by General Electric Co. Replacement ink for the recorder is supplied in plastic inkwells containing 3 oz. The record rolls are 150 ft. long to permit less frequent changing and they utilize light green lines for sharp contrast with the standard red ink. Twenty-eight different chart speeds are available, ranging from ¼ in. per hr. to 2 in. per sec.

For further information circle No. 19 on literature request card, p. 32-B.

Temperature Reading

West Instrument Corp. has announced a system to permit taking nearly simultaneous temperature readings at several points on a single,

centrally located pyrometer. The system consists of several thermocouples connected to a high-resistance pyrometer equipped with a selector switch. The pyrometer, selector switch and terminal strip are all enclosed in a single cabinet, which is equipped for flush or surface mounting.

For further information circle No. 20 on literature request card, p. 32-B.

Recording Potentiometer

A recording wide-strip potentiometer which features full-scale pen travel across the 11-in. chart in only 0.4 sec. has been announced by the Bristol Co. It is offered with standard ranges as low as 1 millivolt for full-scale, with source resistance up to 10,000 ohms. The recorder has been used for recording variables such as those encountered in rocket and jet-engine testing, wind tunnel investigations, and laboratory tests. A specially designed recording pen and pen carriage are used to assure continuous inking at the high speeds, and to prevent damage when the pen comes to the end of the scale.

For further information circle No. 21 on literature request card, p. 32-B.

Surface Roughness

Micrometrical Mfg. Co. has announced a new rotary Pilotor for taking Profilometer roughness measurements around surfaces of rotation on small parts on a production basis. Surface of 1/32 to 2 in. radius or more may be measured, depending on the size of the part. Tracers can be furnished to reach surfaces in parts of almost any shape. It provides both reciprocating and continuous tracing motion.

For further information circle No. 22 on literature request card, p. 32-B.

HOUGHTON RUST VETO can make YOU happy, too!

Yours may not be a problem of keeping the blades of a pocket knife bright and shiny—the way Scouts like them—but this is an example of how Houghton helps in solving rust prevention problems.

In this case, the inhibitor had to keep rust from forming during processing, on the store shelf and in shipment—it had to be free from any effect on the non-metallic parts—and it had to be "invisible".

Houghton's ability to solve "pocket-size" rust prevention problems like this is just a small example of how the complete line of Houghton Rust Vetos can help you in your rust prevention problems. Call on the Houghton Man—outline your needs to him—and costly rust and corrosion losses will be stopped. E. F. Houghton & Co., 303 West Lehigh Avenue, Philadelphia 33, Pennsylvania.

RUST VETO
. . . products of

E. F. HOUGHTON & CO.
PHILADELPHIA · CHICAGO · DETROIT · SAN FRANCISCO

Ready to give you on-the-job service . . .

HERE ARE A FEW OF THE POPULAR HOUGHTON RUST VETOS

RUST VETO 266

Primarily used for the neutralizing of fingerprints, it is actually a combination of rust preventive, cleaner and neutralizing agent. It possesses water displacing properties and forms a thin film on the metal which will remove drops or films of water by preferential wetting of the metal surfaces.

RUST VETO A-2

One of Houghton's oldest and best known preventives. It is a light solvent type which leaves a waxy, firm film, easily removed by solvent.

It is used for indoor protection of highly finished parts, stored or wrapped for shipment, such as tools, dies or gauges. It will withstand over 300 hours in the humidity cabinet at 100°F.

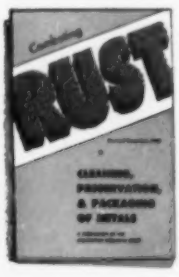
RUST VETO 377

A solvent polar type preventive, outstanding for long term indoor or shed storage. Its water displacing ability is useful in protecting parts already exposed to humidity. Providing a soft but durable .0005" film which can be removed by solvents, this product is applicable at minus 5°F. It withstands 30-day humidity cabinet test at 100°F.

RUST VETO 344

A dark colored solvent solution, free from rosin or sediment, and drying rapidly so as to permit handling within one hour. It is readily removed by solvents.

It is recommended for the protection of metals stored outdoors and other applications where a dry, dark film is desired. This product shows no corrosive tendency toward steel, brass, aluminum or copper. An even film will be maintained down to 20° above zero without cracking.



Write for your copy of "Combating Rust"—a 72-page manual on all phases of rust prevention.

What's New In Manufacturers Literature . . .

43. Abrasion Tester
Bulletins on durable precision instrument for evaluating the resistance of surfaces to rubbing abrasion. *Taber Instrument*

44. Abrasive Cleaning
Catalog 54-W on brush types, sizes, speeds, filaments. Aids to power brush selection. *Pittsburgh Plate Glass, Brush Div.*

45. Abrasive Wheels
Operating suggestions and recommended wheels for finishing stainless. *Manhattan Rubber Div.*

46. Alloy Chart
Comparison of AISI, SAE, ACI, AMS, WAD and PWA chromium and chromium-nickel stainless specifications. *Cannon-Muskegon*

47. Alloy Steel
68-page "Aircraft Steels" includes revised military specifications. Also stock list. *Ryerson*

48. Aluminum Alloy
Folder on plates and bars of copper-silicon-aluminum alloy. Case histories. *Pioneer Tool Engineer*

49. Aluminum Cleaning
48-page booklet gives practical tips on materials and methods of cleaning aluminum and magnesium. *Oakite*

50. Aluminum Die Castings
Bulletin on design and manufacture of aluminum die castings. *Hoover Co.*

51. Aluminum Finish
Bulletin on new invisible finish for aluminum describes Alodine No. 1000 and includes flow sheet for immersion process. *American Chemical Paint*

52. Aluminum Melting
Folder on electric furnaces for the aluminum alloy foundry. *Ajax Engineering*

53. Atmosphere Furnace
Bulletin on controlled atmosphere furnace. *Industrial Heating Equipment*

54. Atmosphere Furnace
Information on mechanized batch-type atmosphere furnaces for gas cyaniding, gas carburizing, clean hardening or carbon restoration. *Dow Furnace*

55. Atmospheres
8-page Bulletin SC-155 discusses following controlled atmospheres: RX, DX, NX, HNX, AX, HX. Compositions, applications, effects on steel, drawings of generators. *Surface Combustion*

56. Barrel Finishing
32-page handbook on compounds for descaling, deburring, coloring, metal cleaning and rust inhibition. *Lord Chem.*

57. Bearings
4-page bulletin on plastic bearing materials. *Dixon Corp.*

58. Beryllium Copper
Bulletin 1 on available alloys, conditions, tempers and tables of sizes and properties. *Penn Precision Products*

59. Black Oxide Coatings
8-page booklet on black oxide coatings for steel, stainless steel and copper alloys. *Du-Lite*

60. Blackening Compounds
Bulletin on blackening compounds for ferrous alloys to AMS Spec. 2485. *Swift Industrial Chemical*

61. Boron Additive
6-page article on use of grainal as boron-additive alloy and properties of grainal steels. *Vanadium Corp.*

62. Brass Alloys
Bulletin on powder metal copper-zinc alloys gives composition, strength, elongation and special features. *Dixon Sintaloy, Inc.*

63. Brazing
Bulletin 124—on salt bath brazing process—shows how it is possible to substitute brass for copper and develop joints of adequate strength for most steel assemblies. *Ajax Electric*

64. Brazing
New 12-page booklet tells how to silver braze with preformed rings. *Lucas-Milhaupt Engineering*

65. Brazing Alloys
File includes physical property data on commercial silver solder and cross index of commercial designations and ASTM and government specifications. *Goldsmith Bros.*

66. Brazing Alloys
Bulletin on application of six types of copper and silver brazing alloys. *United Wire & Supply*

67. Brinell Machine
Data on semi-automatic Brinell testing machine. *Detroit Testing Machine*

68. Carbon Control
Technical report on instrument for control of carbon potential of furnace atmospheres. *Lindberg Eng'g*

69. Carbon Control
Bulletin SC-168 on system for automatically controlling carbon potential in continuous and batch furnaces. *Surface Combustion Corp.*

70. Carbon Dioxide Welding
12-page reprint on carbon-dioxide shielded consumable electrode arc welding. Methods of supplying and flow characteristics of carbon dioxide, properties of weld metal, operating characteristics. *Air Reduction*

71. Carbonitriding
Literature on Ni-Carb (carbonitriding) treatment for surface hardening. *American Gas Furnace*

72. Castings
New 16-page booklet, "Cast to Outlast Destructive Service", gives latest information and case histories on use of sand, centrifugal and precision investment castings. *International Nickel Co.*

73. Chromate Finishing
File on chromate conversion coatings for prevention of corrosion and paint-base treatment of nonferrous metals. *Allied Research Products*

74. Chromium Treatment
Reprint describes how chromium impregnating of steel affects properties, how it is done, applications. *Chromalloy Corp.*

75. Cleaners
Folder on immersion, electrolytic, spray cleaners, phosphate coaters, strippers, drawing compounds, additive agents. *Northwest Chemical*

76. Cleaning
Folder on di-phase cleaning gives equipment, construction features, spray and blow-off features, heating systems. *Solventol*

41. Shot Peening

What is shot peening, how is it controlled and what parts can be peened introduce this 28-page booklet. It discusses applications of peening coil springs, torsion bar springs, leaf springs,

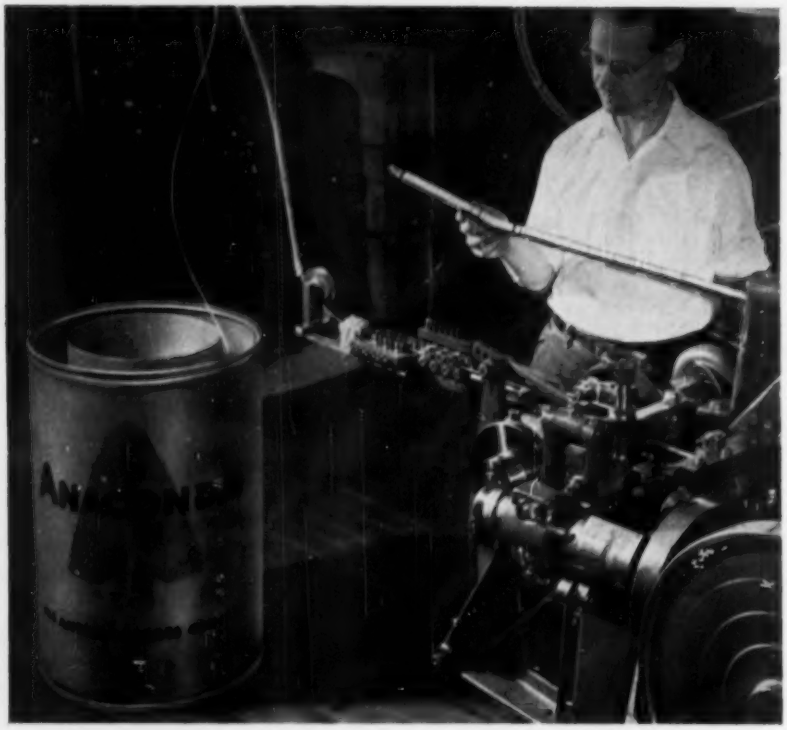
oil well drill pipe, gears, connecting rods and crankshafts. It also considers straightening by shot peening, peen forming, peening before grinding and before chromium plating, peening of nonferrous metals and very hard steel. The book closes with 71 references to articles and books on shot peening. *Metal Improvement Co.*

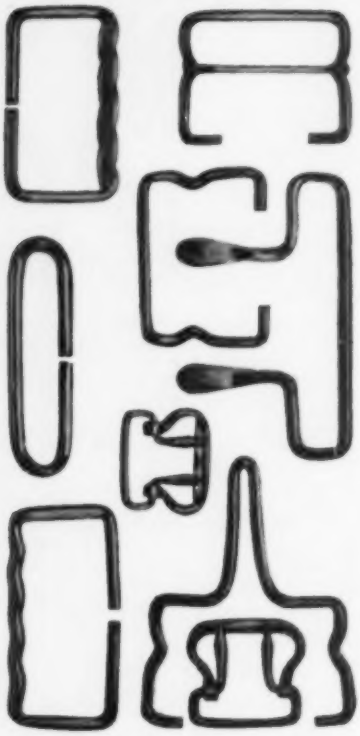
77. Cleaning
Data sheets on acid activators to promote removal of scale and oxides from steel and iron. *Swift Ind. Chem.*

78. Coatings
New Bulletin 7-2 on neoprene heavy duty, extra heavy duty, styrene, chlorinated rubber and epoxy resin based coatings. *Atlas Mineral Products Co.*

79. Cold Finished Steel
16-page booklet on 10 grades of cold finished steels. Analysis, machinability, heat treatment, wear resistance. *Jones & Laughlin*

Anaconda Wire now available in New Pay-off Container





BUCKLES AND BUCKLE PARTS made by West Haven Buckle Co., West Haven, Conn., using Anaconda 70-30 yellow brass wire. Finished buckles, later nickel plated, are of highest quality, noncorroding, for use in surgical bandages, trusses, corsets and other surgical appliances.

Shutdowns to change coils in wire forming machines cut 90% at West Haven Buckle Company

The West Haven Buckle Company of West Haven, Conn., used to be limited to relatively light coils of brass wire because of the slide feed necessary for free pay-off into its wire forming machines. Machines could operate less than an hour before shutdown to feed in another coil.

When they started using Anaconda Wire packaged in the *new pay-off barrel*, which provides free pay-off, the runs were increased 10 times. The big coils of brass wire—400 to 500 pounds—made possible continuous runs of from 8 to 9 hours. This cut the time lost in changing coils 90 per cent. It eliminated the labor of shifting and lifting heavy coils—as the wire is fed directly from the barrel.

An easy way to increase production, cut costs: Big coils of Anaconda Wire in the *new pay-off barrel* give you these advantages:

1. Reduced down-time to change coils can mean production increases up to 25 per cent. Free pay-off feature may enable you to increase machine speed for still greater production.
2. Operators are freed for other duties during the longer continuous runs.
3. Easier handling, better inventory control. Barrels are clearly marked for quick identification—are easily handled by standard hand trucks—utilize storage space efficiently—can be stacked. Losses are minimized because coils stay clean indefinitely—there is no danger of coils becoming tangled or mixed.

No extra charge for Anaconda Wire in the new pay-off container. Call your American Brass Company representative today or write: The American Brass Company, Waterbury 20, Conn.

THE NEW CONTAINER which provides Anaconda Wire in 400 to 500 pound coils, ready for free pay-off into pin machines and other automatic forming machinery. Anaconda wire in all alloys is available packaged this way for long, continuous runs—in all gages up to .090", in tempers at least one number hard.

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COPPER AND COPPER ALLOY WIRE

80. Colored Coil
Folder on aluminum, steel or other metallic coil finished in permanent colors. *Southern States Iron Roofing Co.*

81. Combustion Control
20-page booklet on combustion of various fuels and portable instrument to measure content of oxygen and combustibles. *Cities Service Oil*

82. Compressors
12-page bulletin 126-A on application of turbo compressors to oil and gas-fired equipment used in heat treating, agitation, cooling, drying. Performance curves, capacities. *Spencer Turbine*

83. Continuous Casting
24-page book, "Better by the Mile", describes how the Rossi continuous casting machine works. History of continuous casting. *Scovill Mfg.*

84. Controller
Bulletin 4-11 on electric proportional controllers for dew point, pressure, temperature in batch process, combustion atmosphere and heat treating furnaces. *Foxboro*

85. Controllers
46-page Bulletin 1120 on pneumatic control and transmission systems. Pneumatic controllers and how they work. *Minneapolis-Honeywell*

86. Copper Alloys
64-page book on free-cutting brass, copper and bronze. *Chase Brass*

87. Copper Alloys
24-page manual on alloys in rod form. Typical parts. Specifications covering alloys described. *Mueller Brass*

88. Copper Alloys
48-page book contains tables of alloys with composition, typical uses, general, working, mechanical, electrical properties, hardness, ASTM specification numbers. *Revere*

89. Corrosion of Copper
28-page booklet B-36 discusses corrosive attack on copper and copper alloys. Tabulation of their relative corrosion resistance. *American Brass*

90. Degreasing
34-page booklet on vapor degreasing. Design, installation, operation and maintenance of equipment. *Circo Equipment*

91. Descaling Process
8-page bulletin on sodium hydride descaling process for ferrous and nonferrous metals. *DuPont*

92. Descaling Stainless Steel
Bulletin 25 on descaling stainless steel and other metals in molten salt. *Hooker Electrochemical*

93. Dew-Point Recorder
Bulletin 11-11 on dew-point systems for recording or controlling. *Foxboro*

94. Diamond Polishing
8-page booklet on metallographic polishing with diamond abrasive and its advantages over silicon carbides. *Elgin National Watch Co.*

95. Die Casting
Folder on molds for plastics and die casting dies. Case histories. *Parker Stamp Works*

96. Die-Casting Machines
Copies of "Lester Press" describe various features of aluminum die casting machines. *Lester-Phoenix, Inc.*

97. Dynamometers
4-page folder on precision dynamometers for measuring traction, tension or weight. Capacities from 0 to 500 lb. to 0 to 100,000 lb. *W. C. Dillon*

98. Electric Furnaces
Catalog of electric furnaces and ovens for hardening, tempering, annealing, drawing, drying, baking, enameling. *Cooley Electric Mfg.*

99. Electric Furnaces
Brochure on electric heat treating, melting, metallurgical tube, research and sintering furnaces. *Pereny Equipment*

100. Electric Furnaces
Folder on electric furnaces with zone control, temperature indication, automatic control. *L & L Mfg. Co.*

101. Electric Melting
Bulletin 527 on compact arc furnace. Melt time and power consumption for four alloys. *Detroit Electric Furnace*

102. Electrical Steels
20-page booklet gives magnetization, hysteresis loops, core loss for two steels of electrical quality. *Allegheny Ludlum*

103. Embossed Stainless
Folder on cost advantages, end use advantages and extra dividends. *Rigidized Metals*

104. Environmental Cabinets
New bulletin on cabinets from 1 to 45 cu. ft. capacity, and from +300 to −200° F. ranges. *Webber Eng.*

105. Extrusion
Folder describes the hot extrusion process and gives its history. *Jones & Laughlin*

106. Ferro-Alloys and Metals
104-page book gives data on more than 250 different alloys and metals produced by the company. *Electro Metallurgical*

A BARE THERMOCOUPLE PROTECTS ITSELF FROM FURNACE HEAT.

Not many thermocouples can survive the intense heat and corrosive atmospheres of a furnace. But T-E's tubular thermocouple can. The constantan element is surrounded (and protected) by a thick, tubular, iron element. The iron element is so rugged it acts as its own protection tube and can be used, frequently, without an additional protection tube. Result: high sensitivity. Calibrated to ISA accuracy standards; range up to 1800°F.

Cut away of weld

standard sizes outside dia.	length
9/16"	18", 24", 36", 48", 60"*
13/32"	12", 18", 24"*
1/4"	6", 12", 24"*
1/8"	up to 30 ft. maximum

*Longer, if necessary.

Interested? Write for bulletin 22-H

Thermo Electric Co. Inc.
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CASE HISTORY

HEAT TREATING PRODUCTION UP 25% . . .
SALT CONSUMPTION DOWN 35% . . .
WITH Swift WATER SOLUBLE HEAT TREATING SALTS!

Swift Heat Salts: for neutral heating of all alloy and carbon steels including stainless and high speed steels.

Swift Case for Liquid Carburizing: Energized—Activated—Accelerated to meet all requirements!

Swift Temper Salts: for tempering, bluing and quenching in austempering and martempering operations!

It's a fact! These material savings are expected on virtually every heat treating job because Swift recommends the correct compound for each specific application—then continues to supply salts that are 100% uniform!

Catalog sheets and technical bulletins yours on request.

THE Swift INDUSTRIAL CHEMICAL COMPANY
Albany Turnpike Canton, Connecticut

THE MARK OF QUALITY

BARBER COLMAN

Wheelco Instruments

New

SERIES 8000 POTENTIOMETER-RECORDER

Now available from Wheelco, the Series 8000 Potentiometer-Recorder of null-balancing type, completely self-contained and requiring only an external sensing device. Send for catalog for complete specifications.

FUNCTIONS

Indication • Control • Recording

VARIABLES

Temperature • Pressure • Speed
Strain • Hydrogen Ion (pH)

FEATURES

Maximum accuracy • Simplified operation
Minimum maintenance • Plug-in components
Standard electronic tubes
Wide selection of scale ranges

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Barber-Colman Company
Dept. A, 1518 Rock Street, Rockford, Illinois
BARBER-COLMAN of CANADA, Ltd., Dept. A, Toronto and Montreal, Canada

107. Filler Metal
New colored chart gives complete line of filler metals for welding, metal each is suited to, forms available. *Arcos Corp.*

108. Filters
New catalog sheets on six types of filters—portable, mobile, stationary from 250 to 18,000 gal. per hr. capacity. *Bart-Messing*

109. Finishing Compounds
Set of 4-page brochures on compounds for heavy deburring and cutting, deburring and semi-burnishing, burnishing, cleaning. *Newton Industries*

110. Firebrick
New 28-page bulletin R-34 on properties and characteristics of 5 kinds of firebrick. Typical applications. Tables of brick quantities for arches of different sizes and shapes. *Babcock & Wilcox, Refractories Div.*

111. Flame Hardening
Attractive literature discusses flame hardening of large ways, rolls, etc. *Detroit Flame Hardening Co.*

112. Flame Hardening
New 20-page catalog on flamatic hardening machines and allied equipment. *Cincinnati Milling Machine Co.*

113. Flow Meters
Bulletin 201 on flow meter for gas used in heat treating. *Waukee Eng'g*

114. Fluxes and Grain Refiners
Data sheets on potassium titanium fluoride, potassium zirconium fluoride, potassium fluoroborate give physical and chemical properties, analyses, uses. *Kawecki Chemical Co.*

115. Forgings
12-page booklet on how forged weldless rings and flanges are made. Case histories. *Standard Steel Works Div., Baldwin-Lima-Hamilton*

116. Forming
86-page book on equipment and process of cold roll-forming. Wide sheets, narrow trim, tubular shapes, curving, coiling, tooling needed. *Yoder*

117. Furnaces
6-page folder on gas-fired, oil-fired and electric furnaces. Typical installations. *Electric Furnace*

118. Furnaces
Bulletin 435 on furnaces for tool room, experimental or small batch production. Gas, oil, electric. Muffle or direct heated. *W. S. Rockwell*

119. Furnaces
44-page Catalog 112 features furnaces for hardening, tempering, carbonitriding, forge heating, sintering, annealing and tool heat treating. Also atmosphere generators and ammonia dissociators. *C. I. Hayes*

120. Furnaces
High temperature furnaces for temperatures up to 2000° F. are described in bulletin. *Carl-Mayer Corp.*

121. Furnaces
Data on luminous wall forging furnaces. *A. F. Holden*

122. Furnaces
Bulletin on electric heat treating furnaces describes five series and accessories. *Lucifer Furnaces*

123. Furnaces, Heat Treating
32-page catalog on high-speed gas furnaces for heat treating carbon and alloy steels; also pot furnaces for salt and lead hardening. *Charles A. Hones*

124. Gas Analysis
Data sheet on micro combustion fur-

nace for carbon, hydrogen, nitrogen and oxygen analysis. *C. A. Brinkmann & Co.*

125. Gas Analyzers
Sheet 10.15-14 on applications, operation and features of thermal conductivity-type gas analyzers. *Minneapolis-Honeywell Regulator Co.*

126. Globar Furnaces
Bulletin 153 describes nine types of furnace using silicon carbide heating elements for temperatures to 2600° F. *Hevi Duty*

127. Gold Plating
Article on analysis of gold and gold alloy plating solutions gives all currently available procedures. *Technic*

128. Gold Plating
Folder on salts for bright gold plating. Equipment needed. *Sel-Rex*

129. Graphite Electrodes
Vest-pocket notebook containing 90 pages of information on electric furnace electrodes and other carbon products. *Great Lakes Carbon Corp.*

130. Grinding
31-page booklet on abrasive belt grinding. Applications and advantages. *Engelberg Huller Co.*

131. Grinding
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134. Hard Surfacing
40-page hard facing manual tells what metals can be hard faced, how to select right hard facing material, lists step-by-step procedures and industrial applications. *Haynes Stellite*

135. Hardness Tester
Data on hardness testing scleroscope with equivalent Brinell and Rockwell C numbers. *Shore Instrument*

136. Hardness Tester
20-page book on hardness testing by Rockwell method. *Clark Instrument*

137. Hardness Tester
New bulletin on Wolpert-Gries Micro-Reflex hardness tester for loads from 10 to 3000 g. *Gries Industries, Inc.*

138. Hardness Tester
Bulletin on Brinell Tester with test head for deep and offset testing. *King Tester Co.*

139. Hardness Tester
Bulletin RH-12-54 on portable hardness tester for Rockwell readings. *Riehle*

140. Hardness Tester
4-page bulletin on tester for both superficial and regular hardness testing. *Torsion Balance Co.*

141. Hardness Testers
20-page bulletin on models, applications and how to use superficial hardness testers. *Wilson Mechanical Instrument*

142. Hardness Tester
Bulletin on Impressor portable hardness tester for aluminum, aluminum alloys and soft metals. *Barber-Colman*

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16-page booklet on cost accounting for heat treating. *Metal Treating Institute*

145. Heat Treating
Bulletin describes baskets, crates, trays, furnace parts for heat treating. *Stanwood*

146. Heat Treating Aluminum
New bulletin SC-171 on furnaces, soaking pits, annealers, batch units for heat treating, melting, investment casting aluminum and other light alloys. *Surface Combustion*

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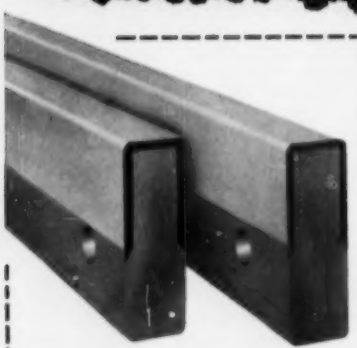

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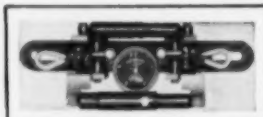

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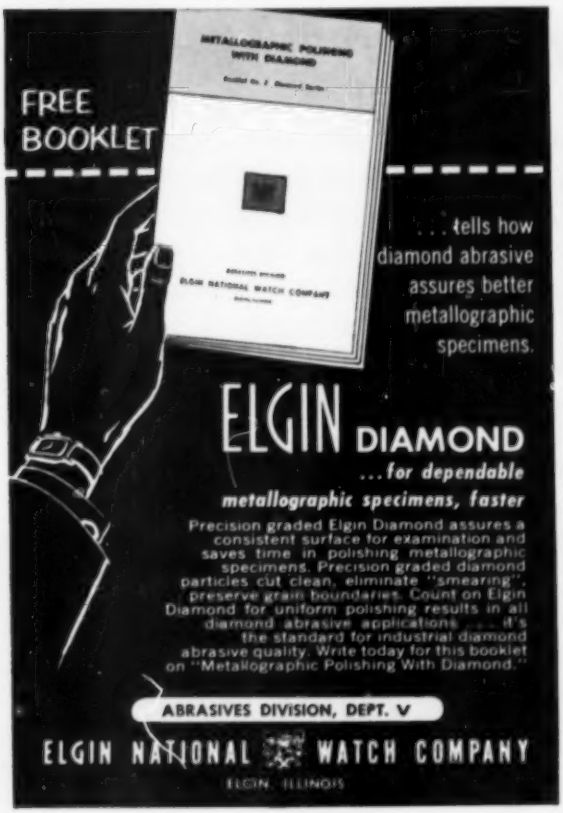
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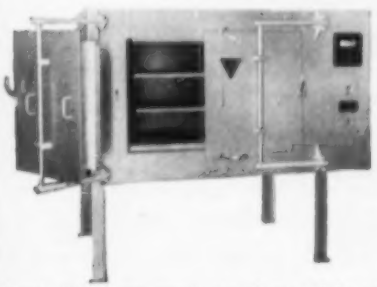

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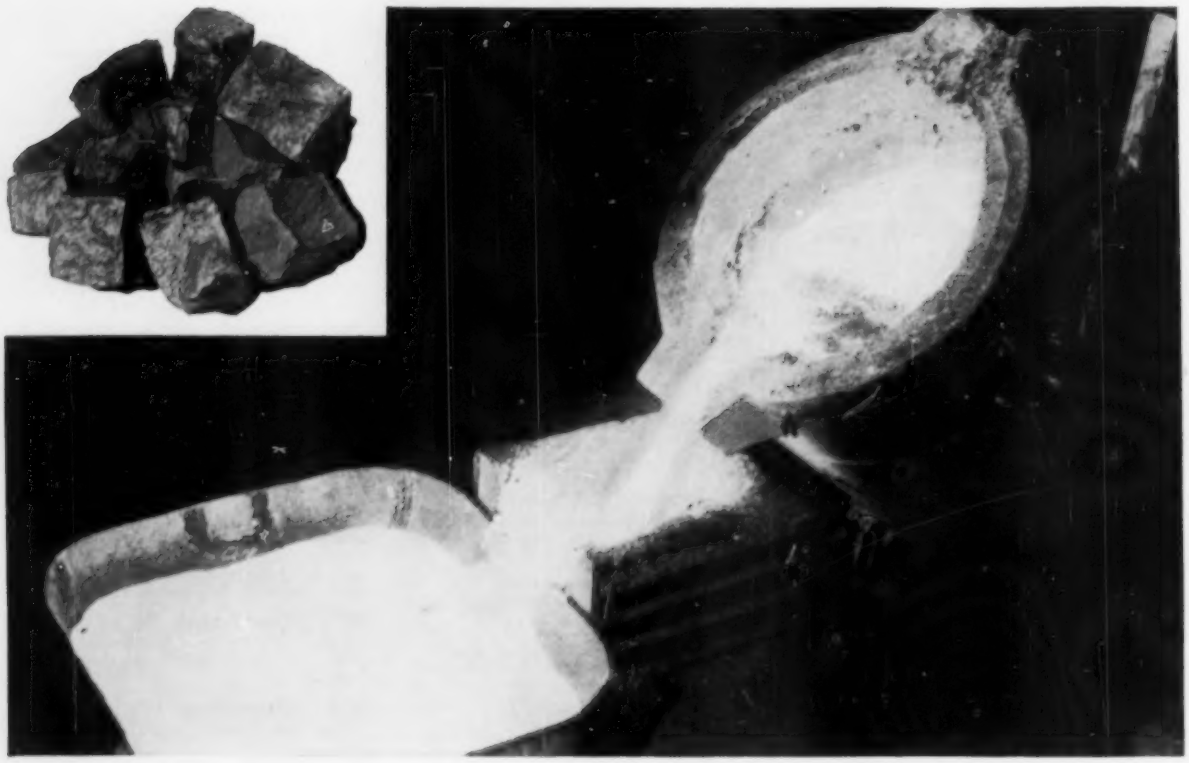

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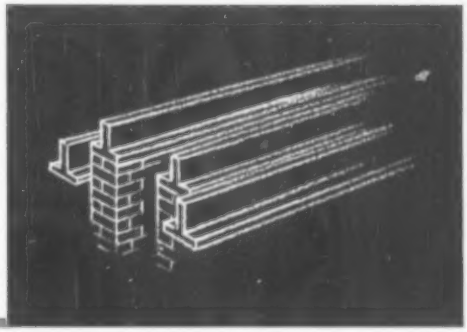

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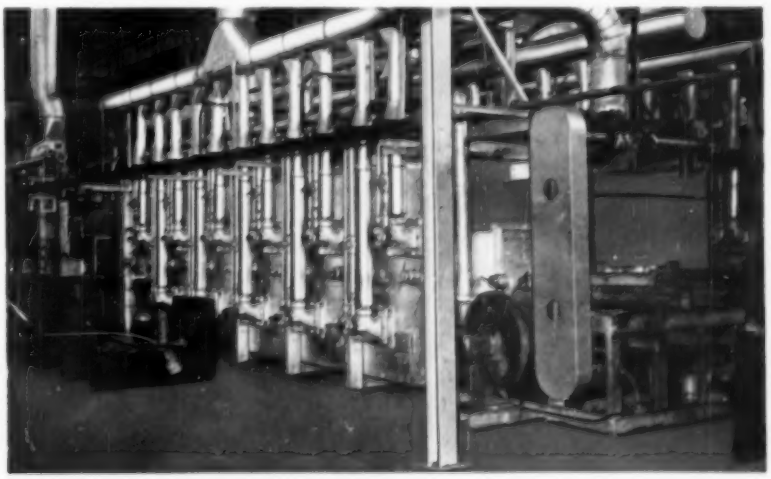

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242. Testing Equipment
80-page illustrated catalog lists over 130 testing and measuring tools for laboratory and production-line use. *General Electric*

243. Testing Machines
Bulletin on Brinell hardness, ductility, compression, tensile, universal, transverse, hydrostatic proving instruments. *Steel City Testing Machines*

244. Thermocouple
Data Sheet on portable molten metal thermocouple and recorder. *Leeds & Northrup*

245. Thermocouple Wire
12-page bulletin No. 1701 lists conductor specifications, insulations for various operating temperatures. *Revere Corp.*

246. Thermocouples
32-page file book on pyrometer accessories. Selection of thermocouple and protective tube. *West Instrument Corp.*

247. Thickness Testers
6-page catalog on Audigage thickness testers. Characteristics and applications of five models. *Branson Instruments*

248. Tin Content
New bulletin F-5609-3 on portable tin content indicators for solder. *Wheelco Instruments Div.*

249. Titanium
8-page book on producing, forming, corrosion resistance of titanium. Health and safety precautions in handling titanium. *Pigments Dept., E. I. Du Pont*

250. Titanium Alloy
Data on ternary alloy with 3% aluminum and 5% chromium gives physical properties, forging temperatures, high temperature characteristics. *Mallory-Sharon Titanium*

251. Tool Steel
Data sheets on high speed, hot work, air, oil and water hardening tool steels, alloy steels, machinery steels, stainless steels, welding rods. *Crucible Steel*

252. Tool Steel Brand Chart
Wall chart listing over 300 popular tool steels by types. *Vulcan Crucible Steel Co.*

253. Tool Steel Color Guide
Color guide to estimate temperatures has heat colors on one side and temper colors on the other. *Bethlehem Steel*

254. Tool Steel Heat Treat
Bulletin 1147EE on electric furnace for heat treatment of high speed tool steel. *Hevi Duty*

255. Tubing
8-page bulletin TB-329B on seamless and welded heat exchanger tubing of stainless, alloy and carbon steels. *Babcock & Wilcox*

256. Tubing
52-page "Handbook of Seamless Steel Tubing". 26 pages of data. *Timken*

42. High Strength Steel
This 22-page booklet describes a free machining, high strength steel which requires no heat treatment. It is compared with other steels as

to resistance to wear, fatigue, machinability, tensile, impact and yield strength and other properties. *LaSalle Steel*

257. Tungsten Alloy
Data on properties and uses of 95% tungsten alloy, balance nickel and copper. *Firth Sterling*

258. Ultrasonic Cleaners
Bulletin on ultrasonic cleaners for instruments. Advantages of use in manufacturing, maintenance and reconditioning. *Pioneer-Central Div.*

259. Vacuum Gage
Folder GEC 986 on molecular vacuum gage for measuring pressures without external detectors. *General Electric*

260. Vacuum Metallurgy
Articles on commercial vacuum furnaces for metals and alloys and some aspects of vacuum melted metals. *National Research*

261. Vacuum Metallurgy
Information memo tells of materials handling in vacuum metallurgy. *Consolidated Vacuum*

262. Vacuum Metallurgy
Information memo describes the high-vacuum technique and pumping systems. *Consolidated Vacuum Corp.*

263. Vacuum Metals
21-page report on vacuum melted metals discusses equipment, properties of metals and their applications. *Ajax Electrothermic Corp.*

264. Vacuum Pumps
New 52-page catalog No. 425 on high vacuum pumps contains formulas and tabular data. *Kinney Mfg.*

265. Vanadium Tool Steels
12-page booklet gives properties, heat treatment, effect of tempering, hardenability of chromium-vanadium tool steels. *Vanadium-Alloys Steel*

266. Welding Alloy Steel
44-page Data Book 4D covers all types of welding of nickel alloy steels. *International Nickel*

267. Welding Electrodes
Report No. W5410 on low hydrogen electrodes for high alloy steels. *Harnischfeger Corp.*

268. Welding Equipment
Catalog on Cadweld process and arc-welding accessories. *Erico Products*

269. Wire
11-page booklet on use of wire in construction of 36 products. *E. H. Titchener*

270. Wire Cloth
84-page booklet on applications, meshes, baskets, filters. *Cambridge Wire Cloth*

271. X-Ray Diffraction
Bulletin 8A-3505 on film or direct recording X-ray diffraction apparatus. *X-Ray Div., General Electric*

272. Zinc and Cadmium Plate
Technical data sheets on use of Luster-on salts for zinc and cadmium plating. *Chemical Corp.*

January, 1956

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"PARK KASE enables us to control

Lakeside uses Park Kase liquid carburizing to control case depths from .003" to .005" specifications. Inspecting several parts that have been case hardened are (l. to r.)

Richard W. Cameron of Park Chemical's Cleveland Office, and from Lakeside Steel Improvement Co., C. Robert Derhammer, Secretary and Metallurgical Engineer; John Ries, Metallurgical Engineer; C. William Derhammer, President; and Michael Tomko, Chief Metallurgist.

case hardness and improve quality"

Says C. William Derhammer

President, Lakeside Steel Improvement Co.
Cleveland, Ohio

"In a big commercial heat treating plant such as ours, it's largely a matter of deciding which method will produce the best results most efficiently.

"When screw machine parts, light stampings and the like are involved we've found that Park Kase 5-C gives us *the* answer. This liquid carburizer enables us to produce a *controlled* light case depth. For instance, when we get selective specifications that call for a depth from .003" to .005" we know we can do it only with a salt bath, and Park Kase has proved quite efficient. Rarely a reject or a rework.

"Another example: Very frequently one customer sends us 5" discs, slightly cupped. Since these are finished and chrome-plated after case-hardening, we can't mar or scratch these discs in any way. Work must be handled carefully, case hardening must be exact, and parts must be clean. So we use Park Kase on this job, too. In fact, when parts vary in shape and design, often they can be handled only by salt bath to achieve satisfactory results.

"We've pioneered as a commercial steel treater since 1924 and for most of that time Park Chemical Co.'s products have been on the job here—successfully."

Park Kase 5-C is a liquid salt bath carburizing compound. It is water soluble, combining ease of cleaning with rapid carburizing rates. PK 5-C is used for long cycle, deep casing applications, with case depths to .050" or more, as well as for light case, high dregout work. Temperatures are in the 1500-1700° F range. Write for technical bulletin A-2.

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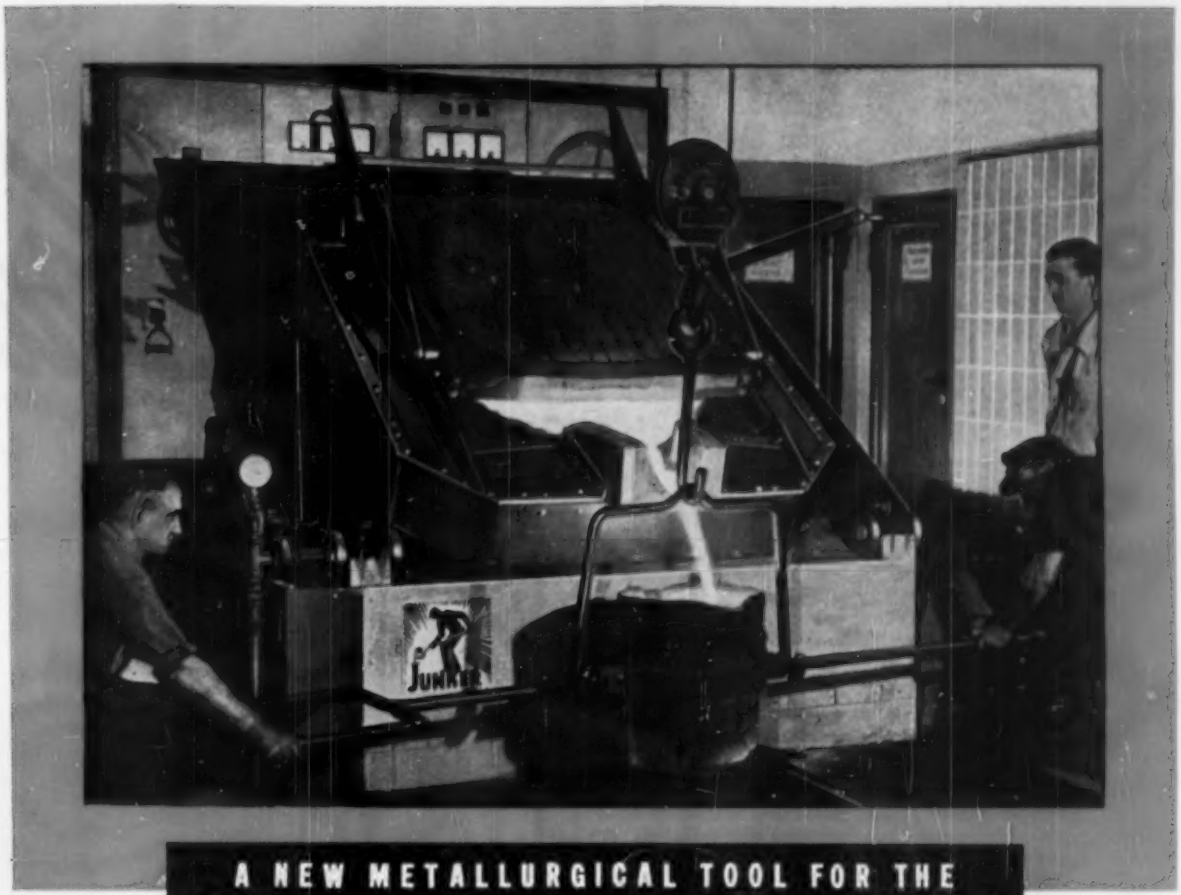

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We offer to the American industry the AJAX-JUNKER 60 cycle induction furnace for the melting and superheating of cast iron, and particularly for the production of ductile cast iron. The AJAX-JUNKER furnace is economical in foundries with intermittent operation and frequent alloy changes. It melts loose turnings with high recovery, and can easily operate at the high temperatures required for desulphurizing. Controlled stirring of the molten metal speeds up recarburizing rate and solution of alloy ingredients.

The photograph shows a Junker coreless induction furnace for melting and superheating cast iron in a German foundry.

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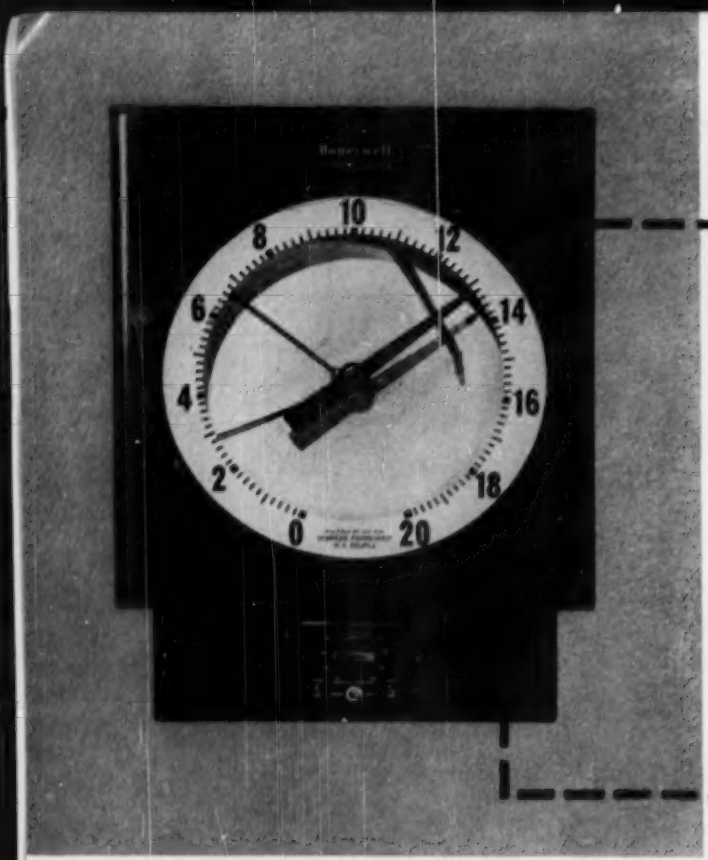
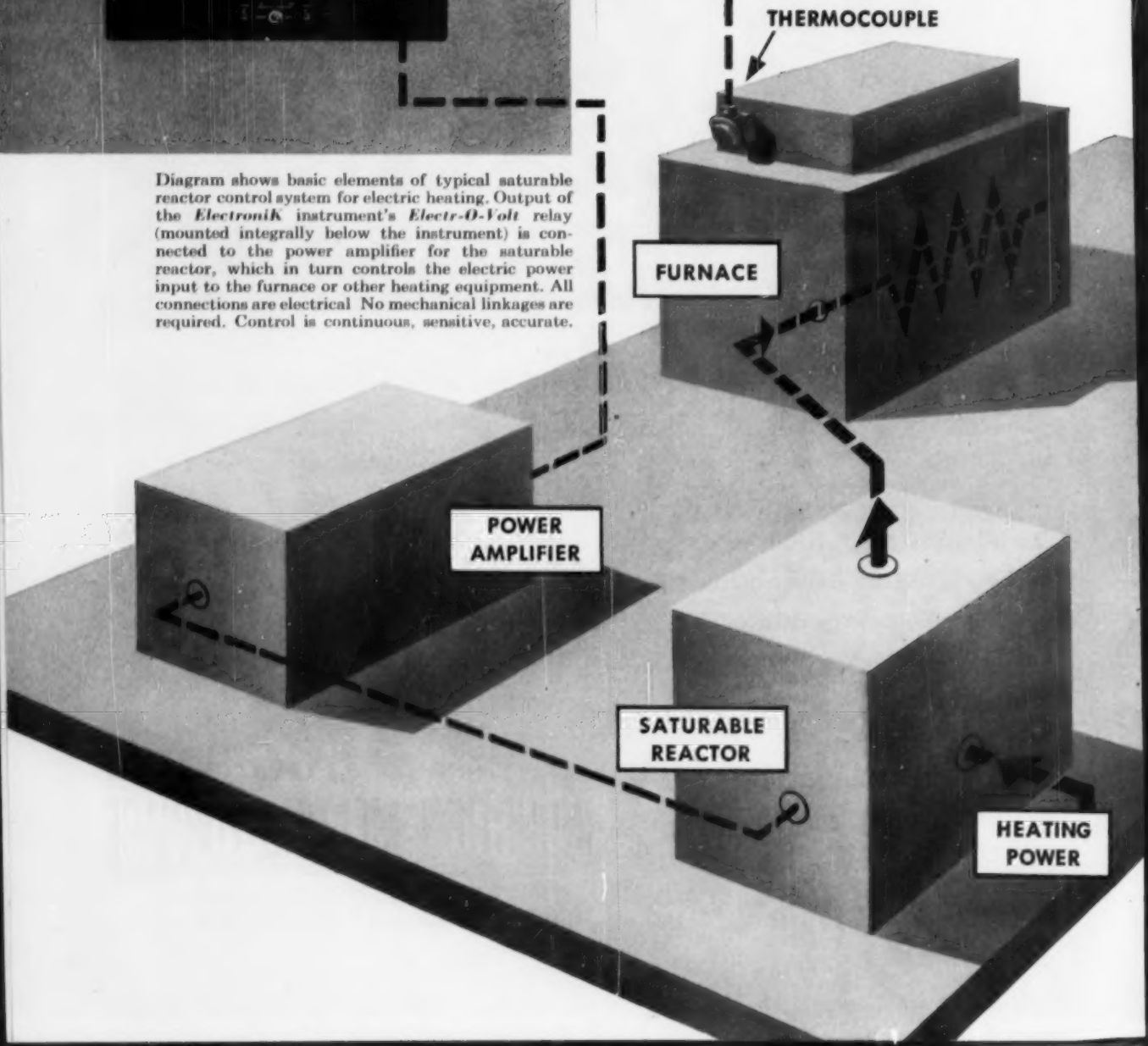


Now

Diagram shows basic elements of typical saturable reactor control system for electric heating. Output of the *ElectroniK* instrument's *Electr-O-Volt* relay (mounted integrally below the instrument) is connected to the power amplifier for the saturable reactor, which in turn controls the electric power input to the furnace or other heating equipment. All connections are electrical No mechanical linkages are required. Control is continuous, sensitive, accurate.



continuous, accurate control of electrically heated equipment

ElectroniK instrumentation with Electr-O-Volt* relay provides continuous throttling in saturable reactor control systems

You can now regulate temperatures of electrically heated furnaces, ovens, and similar processing equipment within exceptionally close tolerances, by using an advanced *ElectroniK* control system in conjunction with saturable reactors. This type of control eliminates the abrupt surges of power and the expense of contact replacement which are frequently objectionable factors of on-off or pulsed electric control.

Continuous control action. The *Electr-O-Volt* relay, actuated by the *ElectroniK* instrument, provides continuously variable control input to the saturable reactor power amplifier. This arrangement gives true proportional-plus-reset control action, which adjusts heat input to compensate for size of load, ambient temperature and other transient and long-term variations in heat demand.

Completely electronic. The system has no mechanical linkages, contactors, or other complex moving parts. Its high speed and sensitivity give the precise control required by modern processes.

Broad range of use. *ElectroniK* control for saturable reactors is applicable to high-temperature heat-treating furnaces, reaction vessels and many other types of electrically heated equipment. It makes possible smooth, finely-adjusted regulation of electric power at high efficiency.

For a discussion of how this control can be applied to your specific problems, call your local Honeywell sales engineer. He's as near as your phone.

Minneapolis-Honeywell Regulator Co., *Industrial Division*, Wayne and Windrim Avenues, Philadelphia 44, Pa.—in Canada, Toronto 17, Ontario.

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● **REFERENCE DATA:** Write for Catalog 1531, "*ElectroniK* Controllers," and for new Bulletin 8420, "*Electr-O-Volt* Relay."

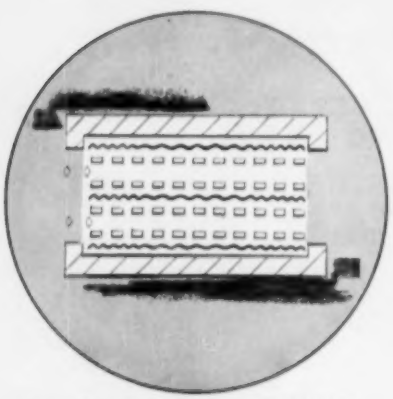
MINNEAPOLIS **Honeywell**

BROWN INSTRUMENTS

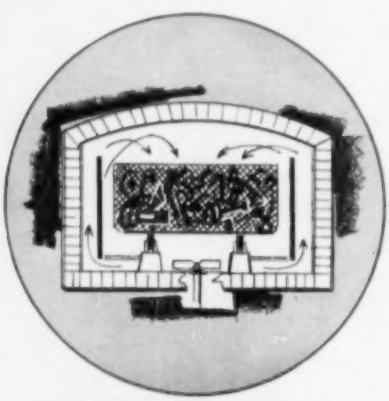
First in Controls

BRAND NEW—MODERN ELECTRIC ELEMENT

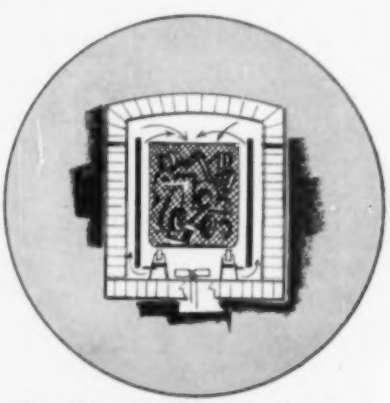
This shows graphically how the new Lindberg CORRTHERM electric heating element actually fills the furnace with walls of glowing heat. Note also that CORRTHERM is conveniently hung from simple brackets requiring no complicated connections or construction. This element operates at extremely low voltage, eliminating shock or short hazards.



In continuous type furnaces CORRTHERM elements hang between lines of work as well as on side walls. Note how closer corrugations (at each end of element) compensate for incoming cold work and door losses.



CORRTHERM elements act as natural baffles to direct forced convection streams through the charge. The use of electric furnaces for carburizing and carbonitriding now becomes completely practical.



No retort needed in pit-type carburizing furnace with CORRTHERM elements. Again see how elements serve as baffles to direct forced convection stream through charge.

FOR LINDBERG FURNACES

Never before has there been an electric heating element like this CORRTHERM by Lindberg. Its revolutionary advantages now make the use of electricity as the source of heat, practical, efficient and economical for all heat treating processes.

Ideal for use in any electric heat treating furnace, CORRTHERM elements have particular advantages for carburizing and carbonitriding. This new element completely eliminates problems formerly created by the use of electricity in these types of furnaces. These exclusive advantages of CORRTHERM explain how and why:

LOW VOLTAGE: Operates at extremely low voltage. No leakage through carbon saturation. Around Lindberg we talk about it as the electric element "without any electricity . . . to speak of!"

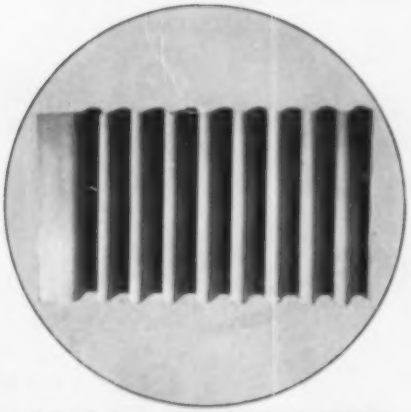
ATMOSPHERE CIRCULATION: Elements act as baffles to direct circulation of convection streams.

SAFETY: Extremely low voltage also eliminates shock or short hazards.

DURABILITY: Watts density at all-time low. Element practically indestructible. Work load or operator's charging tool can't hurt it.

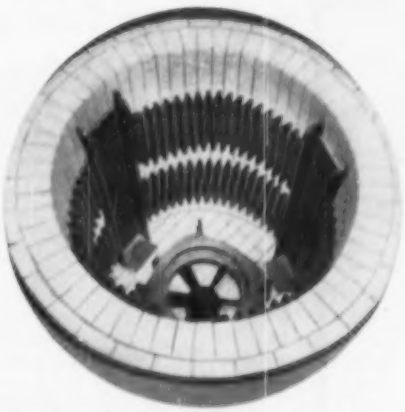
EASILY INSTALLED: Element is not enclosed, just hangs in furnace. No complicated mountings required.

If electricity is the preferable source of heat for your metal treating processes find out how advantageously CORRTHERM elements can be applied to your requirements. Just get in touch with your nearest Lindberg Field Representative. (Consult your classified phone book.)



CORRTHERM elements are large sheets of corrugated nickel chromium. They were developed in Lindberg laboratories by Lindberg metallurgists and engineers.

This shows installation of CORRTHERM elements in one of two large rotary furnaces currently being erected in the field by Lindberg's associate company, Lindberg Industrial Corporation.



An installation of CORRTHERM elements in a carburizing pit-type furnace. Simplicity of mounting makes replacement easy and economical.

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Associate Companies: Lindberg Industrial Corporation, Chicago • EFCO-Lindberg, Ltd., Montreal, Canada
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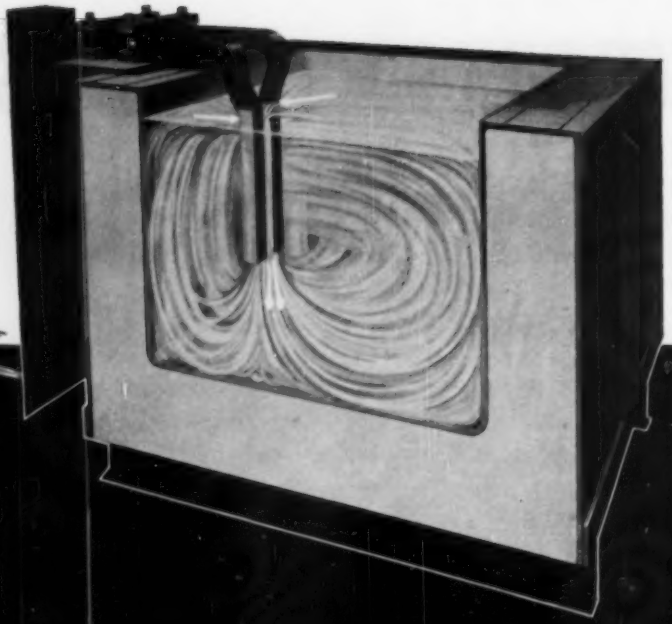
Safety! Extremely low voltage makes CORRTHERM elements completely safe. Let operator or work load bang it if they will. Neither element nor operator will be hurt.

CORRTHERM

by LINDBERG

Suspended-electrode type furnace



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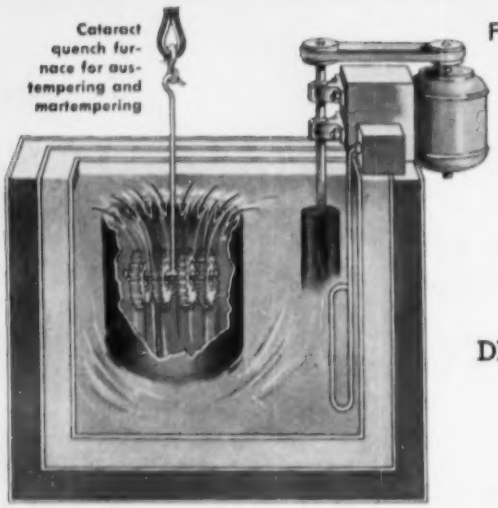

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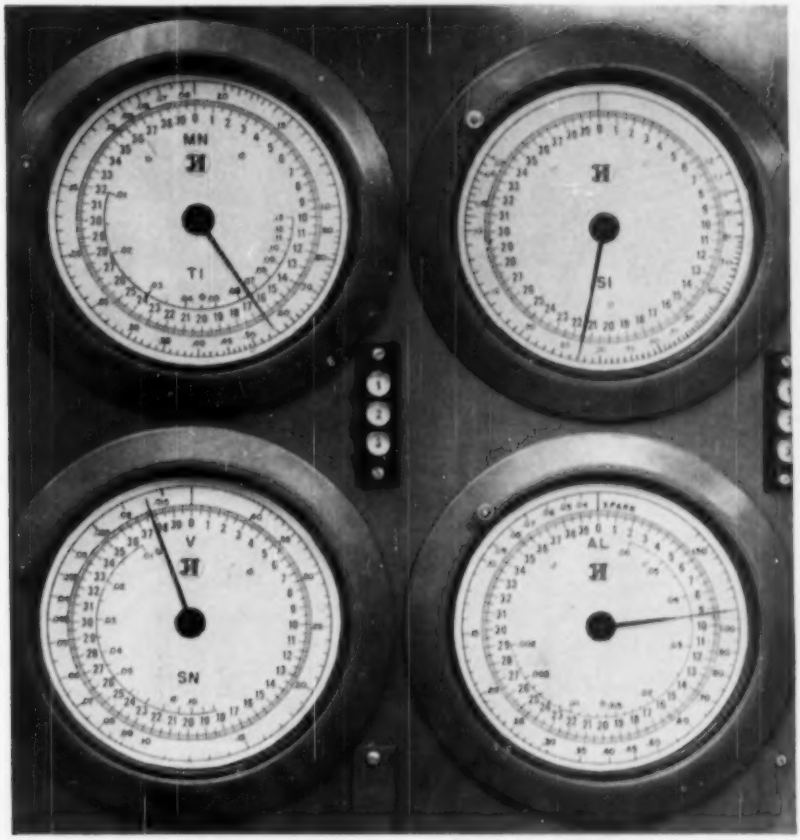

We see what's in TIMKEN® steel while we make it, to give you greater uniformity in your forgings

YOU see above four of the twelve spectrometer dials used to analyze steels being melted at the Timken Company. In just 40 seconds this direct-reading spectrometer tells the exact chemical composition of a heat of Timken fine alloy steel. Results are flashed back to the furnace so the melter can keep close control of the analysis. This carefully controlled chemistry produces uniform composition from heat to heat. You can be sure that forgings made from Timken® forging steels will give you uniformly high ductility and resistance to impact.

And because your order of Timken forging steel is handled individually in our mill we are able to target our conditioning procedure on your particular forging requirements. This minimizes your rejects.

Here's an added plus: Timken steel forging bars *save* you steel because their good dimensional tolerances produce uniform weight multiples with a minimum of steel lost in flashings. Get all these results in your forging steels. Specify Timken forging steels. The Timken Roller Bearing Company, Canton 6, Ohio. Cable address: "TIMROSCO".

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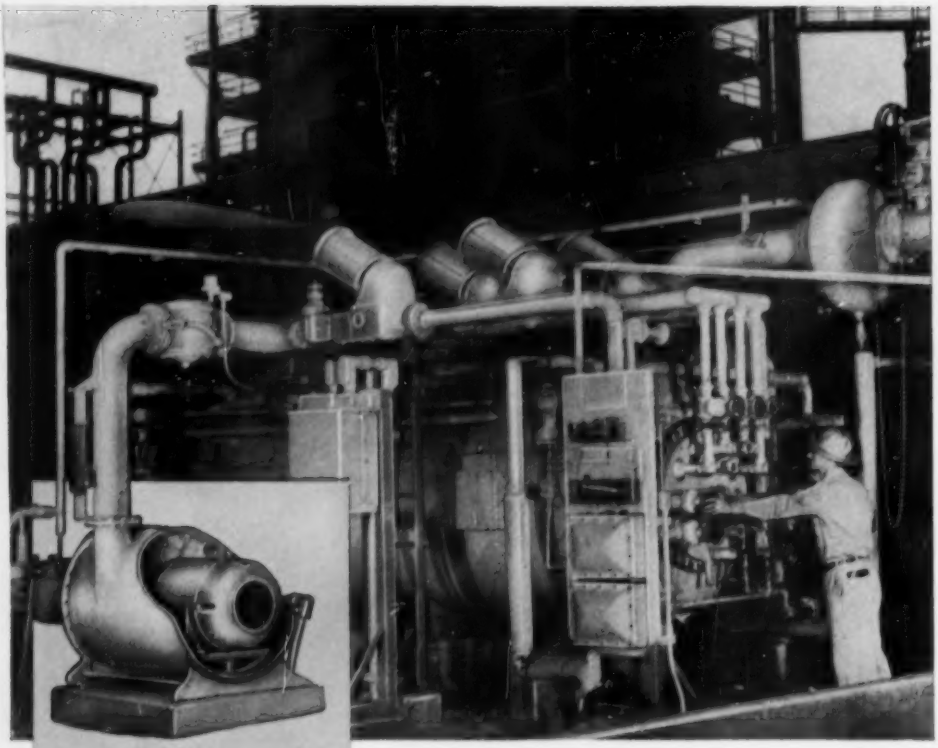

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by
C. M. KEMP
Manufacturing Company

This Kemp Generator produces 60,000 cu. ft. of inert gas per hour for purging pipelines, tanks and crackers at Sunoco Plant No. 5.

The heart of this "Magic Mill" is the Kemp Industrial Carburetor at the left. Air is supplied by a Spencer Turbo with an explosion-proof motor.

Kemp is one of more than thirty manufacturers of oil and gas equipment that have used Spencer Turbos on their products for many years.

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A hundred uses for Spencer Turbos are indicated in Bulletin No. 107. Turbos are described in Bulletin 126.

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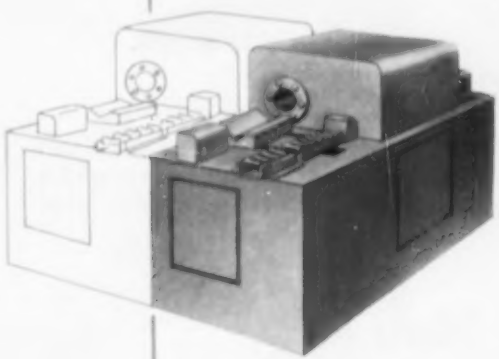

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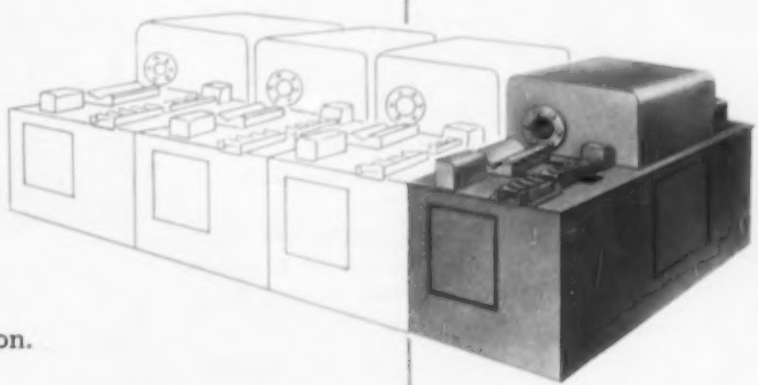

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"Our Production Castings must withstand high pressures without leaks. Our Lesters maintain this high quality and keep our die maintenance costs low."

Others say...

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"We have five of these new Lesters in our plant and they are doing excellent work on our complicated engine castings."

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"The machine is new in our plant, but it behaves beautifully and so far has lived up to all we expected of it."

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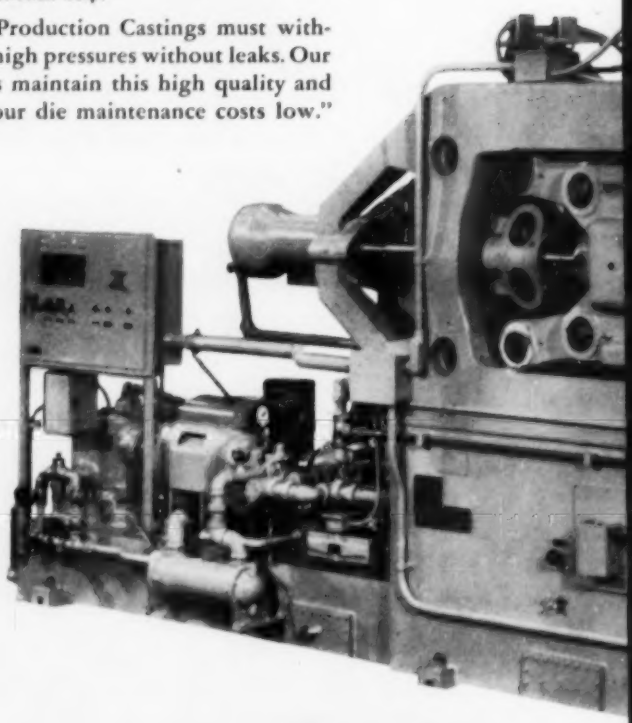

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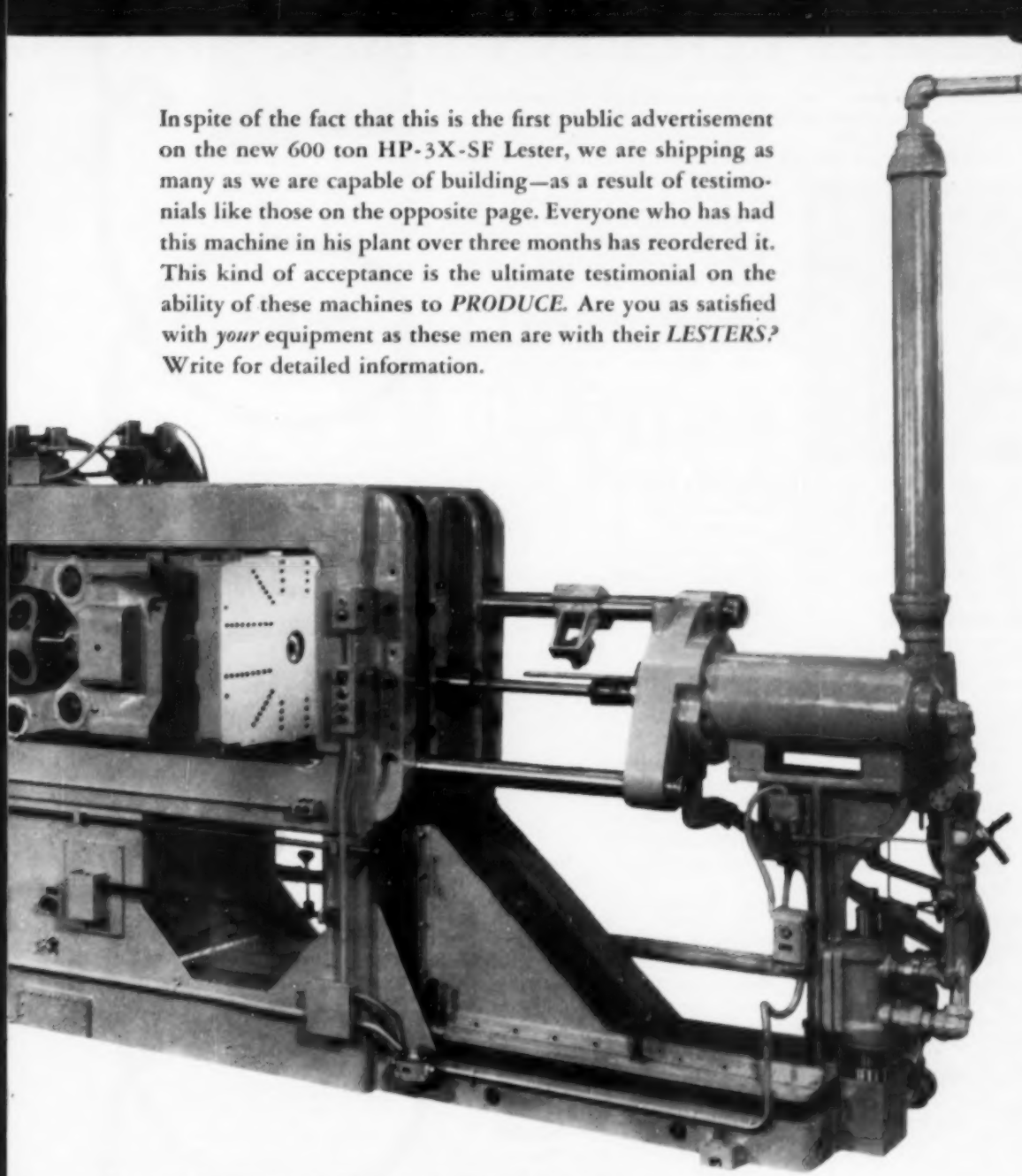

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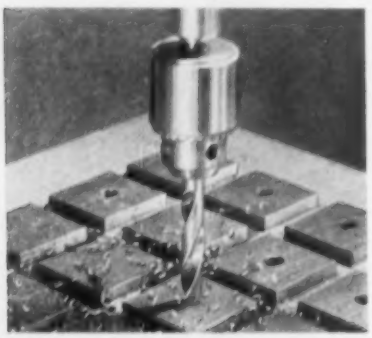
WHAT'S NEW
IN STEEL FROM STOCK

Now—Leaded Plates

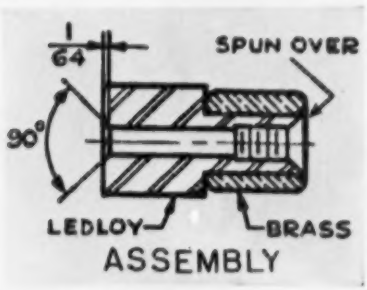
First stocks of leaded steel plates available anywhere are now on hand at Ryerson—and users are reporting results as remarkable as those achieved by thousands of companies with leaded steel bars. Tests show that New E-Z-Cut leaded plates cut faster, take a sounder weld, and polish to a high finish more readily than non-leaded



E-Z-Cut plates. And because sulphur content is much lower New E-Z-Cut is a much cleaner steel, free from troublesome sulphide stringers. First stocks include thicknesses up through 3".

Leaded Bars Make News

Ledloy from Ryerson attracted a good deal of attention at the Chicago Machine Tool Show this fall when three leading machine tool manufacturers chose this amazingly fast-cutting leaded bar steel to demonstrate the efficiency of their latest equipment. For example, the part shown here was machined from Ledloy and assembled with its brass ferrule at a rate of 200 per hour by one tool builder. And at the A.S.M. Show in Philadelphia machining demonstrations showed that the new Ryerson leaded alloy steel Rycut 40 in-



creases tool life up to 300% over non-leaded alloys in the same carbon range. For more details about these demonstrations, and for many other case studies, call Ryerson—where the nation's largest stocks of leaded carbon and alloy steels are available for immediate shipment.

New Fluid Power Tubing

Another development highlighted at the Machine Tool Show is the tremendous increase in hydraulic power applications. And because of this increase, the new Ryerson stocks of light-wall, pump-cylinder finish cold-drawn WELDED tubing should be of interest to a widening group. The special smooth I.D. of this welded tubing often makes it suitable for use "as-is" in place of more expensive types of tubing which still require extra finishing operations. Also in Ryerson stocks for hydraulic applications: Rockrite cylinder finish tubing and hydraulic fluid line tubing.

New Look for Steel Walls

Give steel-walled buildings new beauty with stainless steel siding in mansard pattern, now available for quick shipment from Ryerson. (Galvanized and carbon steel sheets are also available in mansard pattern.) Unusually attractive, economical in total area lost from pattern formation, maintenance-free stainless in mansard pattern also has many industrial and miscellaneous architectural ornamental applications. For new bulletin 70-5, write Ryerson, Box 8000-A, Chicago 80.

Aircraft Steels Specs

Just off the press, a new booklet entitled "Aircraft Steels" contains latest information, in condensed form, on Aeronautical Specifications—Military (MIL), Air Force-Navy (AN), Federal (QQ-S) and AMS aircraft quality steels. Also included is a complete listing of aircraft quality alloy and stainless steels available for quick shipment from Ryerson. To get your copy write Ryerson, Box 8000-A, Chicago 80, for booklet 93.

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Now available from Ryerson stocks: 96" wide plates in thicknesses up through 1", and heavier plates in 80" widths. Types on hand: 304, 304L, 316, 316L. Save welding on next big job with these larger plates.

Carbon Bars, Plates, Shapes

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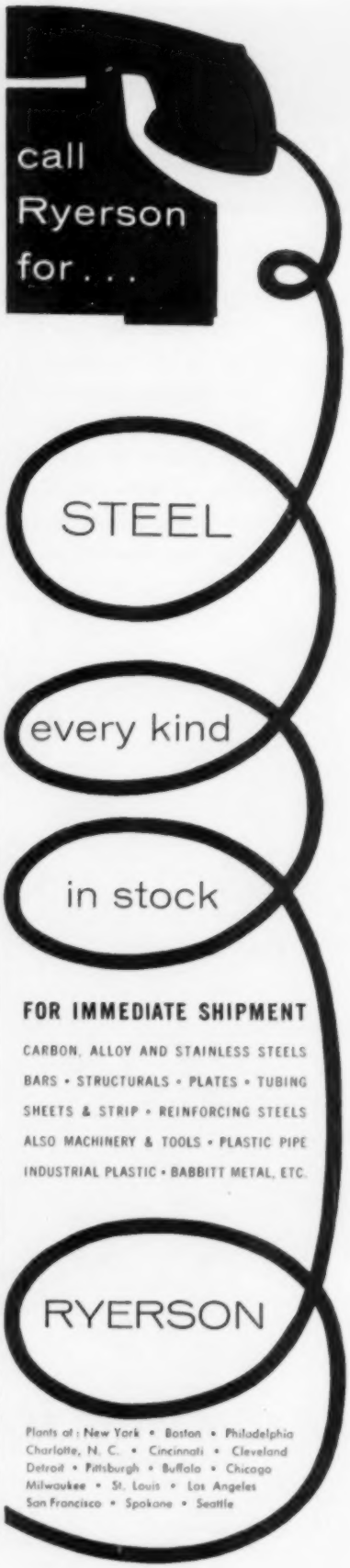
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Metal Progress
Volume 69, No. 1 January, 1956

Fourth Annual Review
of International Progress in Metallurgy

LD-Process of Steelmaking With Oxygen Jet

*By HERBERT TRENKLER AND H. F. HAUTTMANN**

The pioneering plant at Linz, Austria, has made 1,000,000 tons of rimming and fully killed steels, mostly for wire, deep drawing sheets and thin plates. Unusually good weldability and toughness are found in the harder grades. Costs are minimum when working on 80% hot iron and 20% home scrap. (D 8, ST)

DURING the past few years a completely new way of making quality steels in mass production has been developed. The method converts pig iron and refines the steel by the use of pure oxygen only.

The new process (LD-process) worked out at the Linz and Donawitz plants of Vereinigte Oesterreichische Eisen und Stahl Werke Aktiengesellschaft (VOEST), operating successfully for 2½ years, has become of great interest in almost all steelmaking countries because it possesses some of the economic advantages of the basic bessemer process joined with the qualities of openhearth steels.

The economic advantages of both LD-refining and basic bessemer are:

1. Fixed costs and operating costs are low.
2. No fuel is needed.
3. A continuous supply of ingots to the rolling mill is guaranteed.

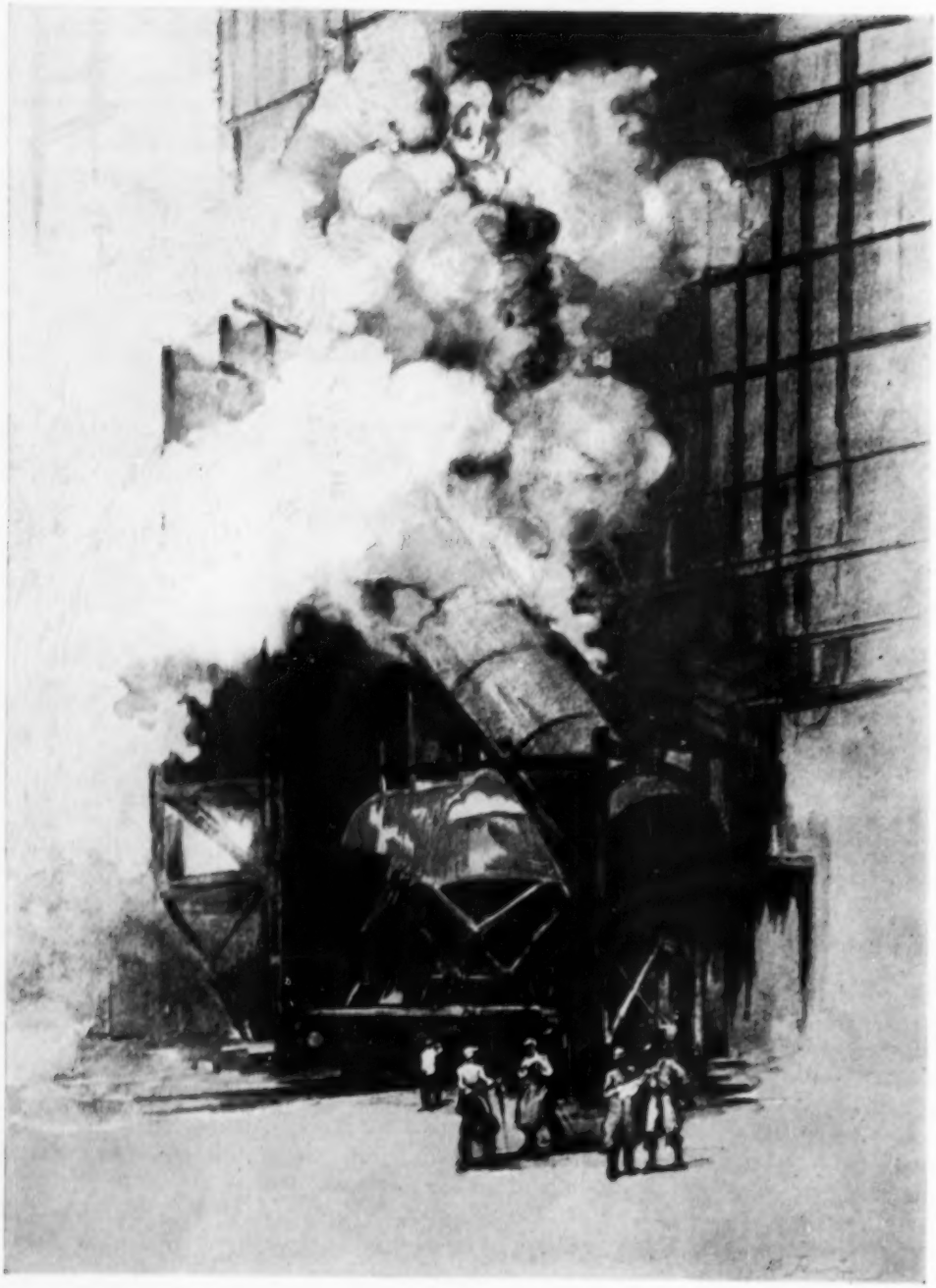
But the basic bessemer process does not approach the LD-process in a few important points besides quality of the steel manufactured:

1. The hourly output of an LD-converter of the same size is greater because there is no loss of time during the after-blow, changing bottoms, and cleaning the mouth.

2. Up to 25% of scrap may be charged into the LD-converter in comparison with a maximum of 10% in the basic converter.

In the LD-process, oxygen of at least 98% purity is blown vertically downward by a water-cooled nozzle on a bath of hot metal. The bath

*Dr. Trenkler is managing director of United Austrian Iron and Steel Works (Vereinigte Oesterreichische Eisen und Stahl Werke Aktiengesellschaft or VOEST) of Linz, Austria, and is author of the first portion of this article on the process. Dr. Hauttmann is director of research for the firm, and is the author of the second portion describing properties of the steels made by the LD-process.



surface exposed to the oxygen jet reacts with great velocity at high temperatures (3500 to 4500° F.) The concentration and specific weight of the locally refined metal differs from the rest of the melt, thus setting up circulation which becomes rather violent. Due to the form of the vessel, the hot metal flows downward from the reaction center to the bottom, moves outward, and rises along the wall, thus continuously bringing new portions of the melt to the reaction zone. This motion insures that the surplus of entrapped oxygen shall react with the melt at some distance from the region just under the jet. That is to say, there is a continuous deoxidation of the newly refined metal. LD-steel is not red-short at the end of the process; oxygen content ranges from 0.020 to 0.040%.

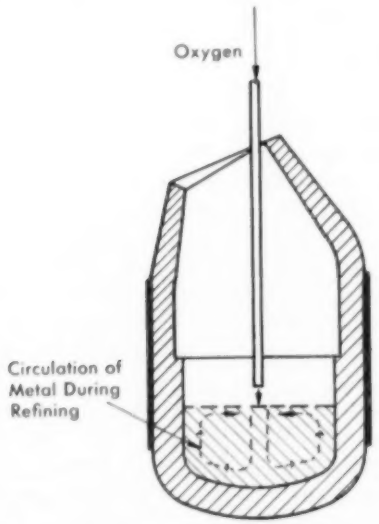


Fig. 1 – Tilting Vessel of Converter Shape Used for LD-Process at Linz, Austria

The LD-process shows the high thermal efficiency of 70 to 75%, compared with only 55% for the basic bessemer process. It can therefore refine pig iron of various types. The iron available at Linz has a composition of 3.8 to 4.2% carbon, 0.6 to 1.3% Si, 1.4 to 2.2% Mn, 0.12 to 0.25% P and a maximum of 0.08% S. Such metal could hardly be handled in the bessemer converter, yet the thermal efficiency allows us to remelt 18 to 25% scrap—just about the quantity of circulating scrap available at a steel plant. The process is, therefore, independent of outside scrap, which is a very important item for countries whose iron industry is based on ore.

Due to the local high temperature a reactive slag is formed very early. Phosphorus therefore drops simultaneously with carbon, so the refined steel not only has low phosphorus but low oxygen as well. The temperature is also high enough to evaporate some iron and manganese, which react with any surplus of oxygen, preventing it from entering into the bath. This evaporation causes the characteristic brown fume to form.

The pig iron used at Linz requires lime additions of 100 to 140 lb. per short ton. The composition of the slag is as follows, and it will be noted that even though using pure oxygen the iron content is normal:

SiO_2	12 to 17%
CaO	38 to 44
MgO	5 to 10
Mn	9 to 12
P_2O_5	1.2 to 1.8
Fe	12 to 18

The average phosphorus and sulphur in the refined steel are about 0.020% each and never exceed 0.025%. Since the oxygen (reagent) has 98% purity, we have a guarantee that the nitrogen content of the steel will be low—about 0.004% and never exceeding 0.006. Increasing the purity of the oxygen diminishes the nitrogen content in the steel. Residual manganese ranges from 0.28 to 0.45%, depending upon composition of the hot metal, quantity of slag, and final carbon content in the molten steel.

Vessel and Charging

The LD-process is carried out in a crucible of converter shape as shown in the painting in color opposite, and of cross section as sketched in Fig. 1. The vessel has a basic lining of tar-bound dolomite bricks made of Austrian dolomite with at least 65% MgO. (The lining next the shell is of burnt magnesite brick.) The excellent durability of the tar dolomite lining allows 240 to 350 melts to be made, provided the oxygen tube is placed exactly along the axis of the vessel. Wear is very uniform and relining is convenient.

The high ratio of operating time means 40 to 45 melts daily from one LD-converter, while one bessemer converter gives only 35 to 40. Relining needs three days. A continuous operation with two LD-converters requires three stands, while operation with two bottom-blown basic bessemer converters requires four stands.

Oxygen is blown through a tube with a water-cooled nozzle of copper. Nozzle leaks are very rare; replacement takes only 3 min.

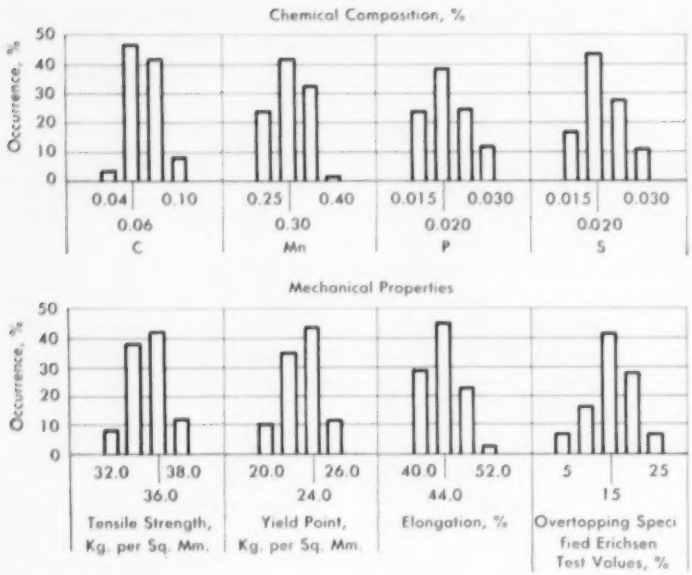


Fig. 2 – Statistical Presentation of Composition and Properties of Rimming, Deep Drawing Sheets, 22 to 20-Gage, 30 Days' Production at Linz by LD-Process. 1 kg. per sq.mm. = 1422 psi.

Charging Procedure – First, scrap is brought to the empty converter in charging pans, slid into the mouth with a chute. Then the hot metal is poured into the vessel. After charging lime into the converter (in a vertical position) the oxygen tube is lowered to correct distance above the metal surface and blowing is started. Blowing takes about 18 min. Sinking of the flame indicates decarburization of the melt to about 0.05% C and the end of the refining process.

After tilting the converter a spoon sample is taken and broken to judge carbon and manganese content. Tapping temperature is controlled by an immersion pyrometer. After slagging off and stiffening up the rest of the slag the melt is tapped. The time, tap-to-tap, is 32 to 36 min.

Output and Oxygen Consumption

Yield in refined iron equals about 90% of the charged metal. The loss of iron in the slag and the loss of oxidizable elements averages about 8.4%. The loss of iron as dust and shot is about 0.8% each. Only very small crusts of iron and slag form on the mouth of the vessel.

By bottom pouring from ladles the weight of large ingots reaches 97% of the refined steel, or about 87% of the charged pig iron.

Oxygen is blown at a pressure of 4 to 12 atm. (55 to 170 psi.). Average oxygen consumption per short ton of steel is 1900 cu.ft. (measured at normal temperature and pressure). A further 65 to 100 cu.ft. is needed for preheating the converter, cleaning the mouth and for work around the pouring pit.

The composition of the dust is about 90% iron oxide, 6% manganese oxide and certain amounts of CaO, SiO_2 and residual elements. Grain size analysis of the dust yields 5% above 1 micron, 45% from 0.5 to 1 micron, 50% below 0.5 micron (0.02 mil). The quantity of dust ranges from 20 to 22.5 lb. per short ton of steel produced.

At Linz we have dust collecting equipment designed by Waagner-Biro and VOEST. The converter gases are first passed through a boiler installed near the stack, where they are cooled from about 3100° F. to about 900° F. This gas is further cooled by a water spray and the wet gas (in which the dust particles are enlarged by condensation) is cleaned in a cyclone dust collector. Gates in the stack also allow the converter gases to escape directly without passing through the dust extractors. To correspond with the existing steam system and the knowledge gained with the pilot plant, the boiler was designed for an average capacity of 44,000 lb. per hr. and a pressure of 640 psi., superheated to 800° F. If blowing time is 18 min., 15,500 to 17,500 lb. of steam is produced per blow.

Economy

Manufacturing cost of LD-steel averages 55% that of openhearth. This figure, of course will vary depending upon local conditions. In Linz the factors are as follows:

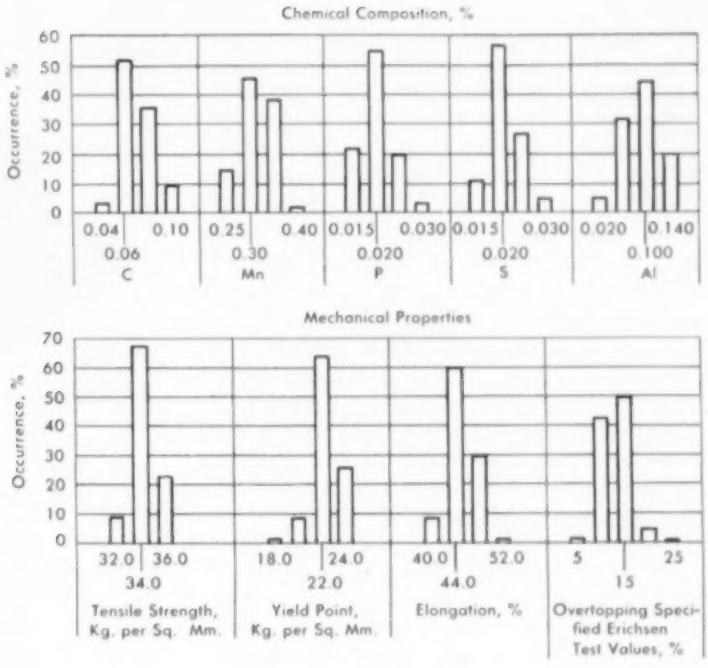


Fig. 3 – Composition and Properties of 30 Days' Production of Killed Deep Drawing Sheets of LD-Steel, 0.030 to 0.050 in. Thick.

1. Labor—The output of LD-steel per man-hour is double that of the openhearth plant.

2. Refractories—The normal consumption of refractories in the openhearth furnace ranges between 32 and 40 lb. of brick and 36 and 50 lb. of dolomite per short ton of steel. The corresponding figure for the LD-converter is 10 to 12 lb. of dolomite.

3. Energy for producing 2000 cu.ft. of dry, 98% oxygen is to be contrasted against 3,200,000 to 4,300,000 Btu. per short ton of steel needed for the openhearth furnace. In most places the ratio of cost is about one third.

The fixed costs of an LD-steel plant are 50 to 60% of those for an openhearth plant of equal production. Depending upon the capacity of the rolling mill and of the production program, the continuous supply of ingots from an LD-plant may save considerable money in the soaking pit department.

The cost of the metal consumed by the LD-steel is related to the percentage of scrap added, and the relative costs of pig iron and scrap. Wherever openhearth steel production is based on pig iron and scrap available at home plant the raw materials are more difficult to handle into an LD-converter. If scrap is available in large quantities at low prices charging costs of openhearth steel are reduced accordingly. Economy of the LD-process is insured as long as the low charging costs of openhearth steel are balanced by the low working and investment costs of LD-steel.

Part II – Steel Properties

In all the European countries producing steel by both openhearth and basic bessemer, a wide range of application of unalloyed, high-tonnage quality steels is reserved to the openhearth process. These are:

1. Low-carbon steels which have to withstand heavy cold working in processing.

2. Low and medium-carbon steels for heavy stresses, such as for ships, boilers and bridges, and high-strength, low-alloy steels with high yield point ratio, and resistance to cleavage fracture in welded construction.

3. Plain carbon steels with a wide range of carbon content for forgings, machine parts and tools, subjected to precise heat treatments.

Our experience during 30 months with the world's first LD-plant at Linz has proved this new steel equivalent to openhearth in all the above applications.

Rimming Steels—LD-steel is characterized not only by low nitrogen, phosphorus, sulphur and oxygen contents, but also by low amounts of tramp elements.

Most of these tramp elements in the pig iron or scrap are reduced by evaporation. Though

the Linz pig iron is very low in residual elements, analysis of the dust spread over the steel plant's roof shows 8.8% Mn, 0.083% Cu, 0.062% Cr, 0.135% V, 1.01% Zn, 0.69% Pb and 0.22% Ti. This experience parallels that of operators of vacuum melting furnaces, where condensed fume scraped from the chamber walls contains elements little suspected in the raw materials. It has been suggested that the enhanced ductility, toughness and fatigue resistance of vacuum-melted metals is due in part to the absence of these trace elements in the finished steel.

About two thirds of the production in the VOEST LD-plant is rimming, low-carbon steel. Nearly half of this is delivered to foreign cold reducing mills for tin plate; an equal portion is rimming high-quality, deep drawing steels conforming to particular specifications.

Chemical composition and mechanical properties of rimming deep drawing sheets, 20 to 22-gage, produced in our own rolling mill are shown statistically in Fig. 2. About one eighth of this is rolled into enameling stock, and it is quite suitable for this application.

In producing rimming steel for soft wire, LD-steel behaves like openhearth of best quality. Its composition is 0.05 C, 0.00 Si, 0.28 Mn, 0.022 P, 0.019 S, 0.000 Al, 0.004 N_2. Wire rod is 0.216 in. diameter, and as rolled has ultimate tensile strength of 50,000 psi. Drawn without annealing to 0.047 in. diameter, its strength is increased to 140,000 psi., and ductility as measured by bending test is as shown at the top of the next page. After aging two months and drawing without annealing to 0.012 in. (cold reduction of 99.7% from original rod) the ultimate strength was

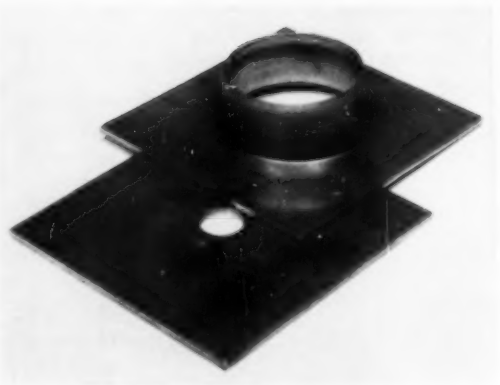


Fig. 4 – Hole Expanding Test on Cold Rolled LD-Steel Sheet 0.040 in. Thick. Drilled hole 0.473 in. diameter expanded to 1.575 in.

Fig. 5 – Weld Bead Bend Test (Kommerell Test) Made According to Austrian Standard M 3052. Tensile strength 52,500 psi., thickness 3.15 in., rimming LD-steel.

	Drawn 95.5%	Aged and Drawn 99.7%
Bends to 5 mm.	16 to 18	37 to 38
Bends to 2.5 mm.	7	10 to 11
Twists in 200-mm. length	56 to 62	182 to 211

200,000 psi. LD-steel is especially characterized by little scatter in test values for alternating bending and torsion for fine wire.

F. J. McMulkin, chief metallurgist of Dominion Foundries, first Canadian steel plant to install the LD-process, has recently confirmed our experience at Linz. He pointed out that there is no difficulty in making a uniform and satisfactory quality in rimming low-carbon steel as well as in annealing after cold reduction.*

Killed Steels – At Linz one third the present production of LD-steel is killed, high-quality, deep drawing steels, part going to the plant's own production of deep drawing sheets, but the greater portion being exported to foreign mills. A good deal of it is aluminum bearing, containing only traces of silicon. Aluminum is added into the ladle when tapping, which would be impossible but for the low oxygen content. Comparing deoxidized openhearth steel with LD-steel, lower additions of aluminum yield the same percentage of soluble aluminum. This is also verified by the experience at Dominion Foundries.

*"Oxygen Steelmaking: How Canadian Plant Uses New Process", by F. J. McMulkin, *Iron Age*, March 1955, p. 75.

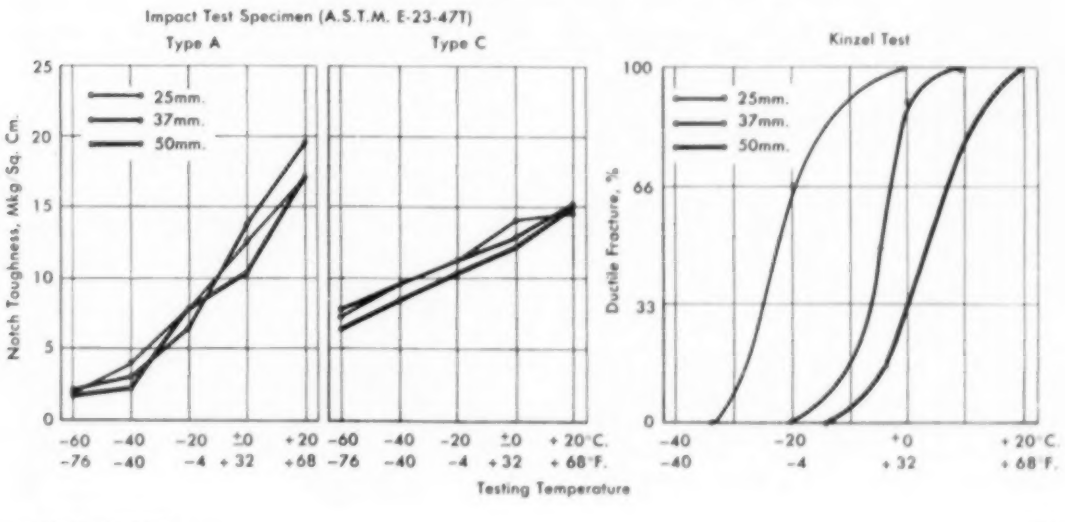
Deep drawing sheets of killed LD-steel, with soluble aluminum contents of 0.1% and more, have extraordinary cold workability in practice. Composition and properties of sheets are shown in Fig. 3. Deep drawing quality may also be gaged by the hole-expanding test suggested by the German Iron and Steel Research Institute (*Mitteilungen*, 1930, p. 115) illustrated in Fig. 4. It is much easier to get a full widening of a drilled 12-mm. hole to 40 mm. in diameter (0.473 to 1.575 in.) with sheets from killed or rimming LD-steel than with deep drawing sheets from openhearth steel.

Weldability – Welded construction demands steels resistant to brittleness – that is to say, low sensitivity to cleavage fracture caused by local effects of welding and influenced by dimensions of the cross section which determine the internal stress conditions. In Austria, thickness of medium steel plates for heavier stressed welded constructions is limited to 1.182 in. for rimming openhearth steel in the as-rolled condition.

In order to test the tendency to cleavage fracture the "weld bead bend" or Kommerell test (somewhat similar to the Kinzel test) is specified in Austrian standards. Plates as-rolled from rimming openhearth steel, 1.575 in. thick with a tensile strength of 52,500 psi., will rarely withstand the bend to angles specified. Thicker plates of rimming LD-steel have no difficulty, as shown in Fig. 5.

Consequently, this steel was furnished in thick-

Fig. 6 – Charpy and Kinzel Tests on Fully Killed, Fine-Grained, Normalized LD-Steel for Shipbuilding, 1, 1.5 and 2 In. Thick. 10 m-kg. per sq.cm. = 36 ft-lb. in the 10 × 5-mm. Charpy test.



nesses up to 1.575 in. for Vierendeel truss bridges erected in 1954 at Neuchatel, Switzerland. Trusses of this design are the first ones built after the collapse of three such bridges over the Albert Canal in Belgium in 1938.

In 1953 similar LD-steels for shipbuilding were tested for certification in a program worked out with authorities. Some 3600 closely supervised tests were carried out, with the result that Det Norske Veritas admitted LD shipbuilding steel in all grades, and British Lloyd and Bureau Veritas for steel in two grades (P 401 and P 402). German Lloyd permits fully welded ships to be built of LD-steel of all grades.

To give some indication of the quality of these steels, Fig. 6 has been prepared showing Charpy impact values for A.S.T.M. standard Type A test pieces (round-bottomed V-notch 2 mm. deep) and Type C test pieces (round-bottomed milled slot, 5 mm. deep), for plates of steel P 403, 25, 37 and 50 mm. thick (1, 1.5 and 2 in. respectively). In A.S.T.M. specification A 300-52 T for steel for pressure vessels for low-temperature service we find that the average of three Charpy values for Type C specimens shall be 15 ft-lb. or greater at −50° F. for Class I steel plates of flange or firebox quality, and at −75° F. for Class 2 steel of firebox quality. The thickest plate shown in Fig. 6 has 6.5 m-kg. per sq.cm. resistance at −76° F. for Type C test piece (0.5 sq.cm. in area), and this is roughly equivalent to 23 ft-lb. in the Charpy test – well above American specifications for Class 1 and 2 carbon steels for low-temperature service.

Figure 6, moreover, shows the transition temperatures from ductile to brittle fracture and their relations to plate thickness and testing temperature determined by the fracture appearance of Kinzel test specimens. According to this the transition temperatures of 1, 1.5 and 2-in. plates are −30, −5 and +25° F. respectively.

Suitability of 2000 tons of high-tensile LD-steel for welded construction was acceptable to the constructors of a welded bridge far in the north of Europe, in Finland. The specifications called for a tensile strength of 75,000 to 87,500 psi. and a yield point of at least 51,000 psi. Notch-toughness at low temperatures (−20° C., or −4° F.) had to be guaranteed in both the nonaged and the aged condition.

Certainly LD-steel is also suitable for boiler plates in all grades, including those with low alloy. Acceptance tests are in preparation. It is also planned to weld part of a large penstock in LD-steel. In preliminary work on this project a tube 45 in. in diameter, 10 ft. long and 0.787 in. thick was made and tested to destruction. The plates showed a yield point of 60,000 psi. and a tensile strength of 86,000 psi. The chemical composition was 0.18% C, 0.26% Si, 1.6% Mn, 0.44% P, 0.019% S and 0.002% N.

This tube was welded from stress-free (annealed) parts and not heat treated after welding the circumferential seam. Just before fracture occurred at a pressure of 2920 psi., elongation of 10% in the circumferential seam was measured. The fracture was ductile.

Seamless tubes in different sizes have been recently produced from ingots of LD-steel yielding satisfactory results.

Steels for Forgings – There are no difficulties in producing steels with carbon contents up to 0.5% and even more. As a rule, refining of the melt is stopped at 0.05% carbon and the metal is recarburized during tapping, preferably by adding powdered electrodes. The properties of a typical steel analyzing 0.55% C, 0.21 Si, 1.00 Mn, 0.031 P, 0.010 S, 0.035 Al and 0.004 N, made into a 120-lb. rail, are as follows:

	Rail Head	Rail Base
Yield point	66,000 psi.	75,000 psi.
Tensile strength	122,000	126,000
Elongation	15.7%	14.4%
Reduction of area	33.0	33.0

Very impressive are the figures for permanent set obtained by the "foot bending test" specified by the Swiss Railways. A permanent set of 4 mm. (0.16 in.) minimum is to be guaranteed at room temperature. Test results with LD-steel rails attained 10 to 18 mm. (0.40 to 0.70 in.) down to as low as −30° C. (−20° F.).

Jominy end-quenching tests on LD-steels corresponding to A.I.S.I. 1035 and 1045 were compared with those of corresponding electric furnace steels and no difference was found.

Summary

LD-process represents an entirely new type of steelmaking, yielding satisfactory economics and quality. No other process can compete in production costs when making high-quality steel using about 80% pig iron and 20% scrap on the charge. Tests show that LD-steel is superior to open-hearth steel in quality. All grades of commercial steels, unalloyed and low-alloyed, up to 0.55% carbon can be produced.

The LD-plant at Linz, Austria, first LD-plant in the world, has now produced 1,000,000 short tons, proving the acceptability of the new steel in many applications.

Extruding Metal With Glass Lubricants

By J. DELCROIX*

Use of glass-wool "sock" or powdered glass as lubricant between hot billet and chamber and die in an extrusion press gives much easier and faster working conditions, better surface on the extrusion, requires less power, and vastly increases the adaptability of the process. Scale-free heating of the billet remains a difficult problem. (F 21, F 24)

A BRIEF DEFINITION of extrusion is that it is the pushing of a heated piece of metal, enclosed in a container, through a die. This simple statement underscores the main characteristics of extrusion:

1. The metal, being enclosed in a container, is subjected to hydrostatic pressure which eliminates the possibility of fracture from tensile stresses.

2. The die is not a critical tool. It is cheap and readily interchanged; this makes the process adaptable to various shapes (cross sections).

3. The only restriction on the die opening is that it be inscribed in a smaller diameter than that of the chamber containing the billet to be extruded. It can be of any shape.

Extrusions need not be solid bars or shapes. Tubes can be extruded by pushing hollow billets through the annulus formed between a mandrel which extends into a circular die. Furthermore, tubes with outside profiles other than circular are readily extruded through dies of the appropriate shape.

This simple description suffices to show that extrusion is almost an ideal metal forming process! It has, indeed, been very widely used for nonferrous and light alloys which can be extruded at moderate or low temperatures. Where operating temperatures are necessarily higher – as in steel extrusion – difficulties appear of such importance that the process has not been widely adopted by the steel industry. One principal difficulty has been the dies. Obviously for economy's sake these are not massive chunks of metal and they are therefore quickly heated up when the temperature (for steel) runs as high as 2200° F. Unless special precautions are taken, they wear out quickly at this temperature. Consequently, extrusion was hardly used at all for steel before World War II except for the stainless steels, high-nickel and chromium alloys, and a little plain carbon steel of ordinary quality. Extrusion of steel shapes, to the author's knowledge, had never been done commercially prior to 1940.

During the occupation years (1942 and 1943), the Comptoir Industriel d'Etirage et Profilage de Metaux and the Ugine steelworks, at the behest of the Germans, undertook to reduce to practice the process now known as the Ugine-Séjournet extrusion process. It had been under study by Jacques Y. P. Séjournet and Louis Labataille since 1938 in a small plant in Paris, but heavy extrusion machinery had not been installed in 1939. The solution of the problem rested on two basic ideas: first, heating the billet in a barium chloride salt bath, thus eliminating scale; and second, the use of glass disks placed in the extrusion chamber against the die ahead of the heated billet. The glass would soften under the effects of temperature and pressure and produce a lubricating film that greatly facilitated the operation.

The technique of lubricating the billet has gone through much evolution since those early days. Softening of glass has been systematically studied – at times theoretically, at times experimentally (notably by radioactive tracer techniques) and important improvements have been made over the original methods.

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The glass disk used in the early work was replaced by fiberglass and finally by glass powder. The last mentioned is by far the best. In the same way, the mandrel used for hollow shapes was originally lubricated with glass tubes (the first trials being made with chimneys from old-fashioned kerosene lamps!), then with a glass cloth either as tape or a woven sock. Present practice is based on glass powder.

This improved lubrication has changed the flow or "extrusion pattern" from the herringbone fiber traditionally illustrated in the literature for extruded shapes. When there is little or no lubrication, the forward face of the billet is converted into the skin of the extruded bar. This necessarily leads to large elongations within this surface metal and to frequent surface defects when metals are difficult to extrude. Extruding with glass, on the other hand, causes the metal to flow in parallel lines. Each part of the billet (viewed as a slice of metal perpendicular to the extrusion axis) proceeds out of the die one after another. Deformation is no longer a critical factor, and metals are easier to extrude.

Heating the Billet

Heating techniques, on the other hand, have not been improved since the first installation, although they ought to be studied a good deal since scale-free heating is a general problem for the entire metals industry. In all fairness it can be said that large tonnages of steel are heated for extrusion without excessive oxidation — but the problem of scale-free heating is normally greatest with billets of small volume, and especially of small cross section where heating rates are fast. Various solutions to the problem have been tried.

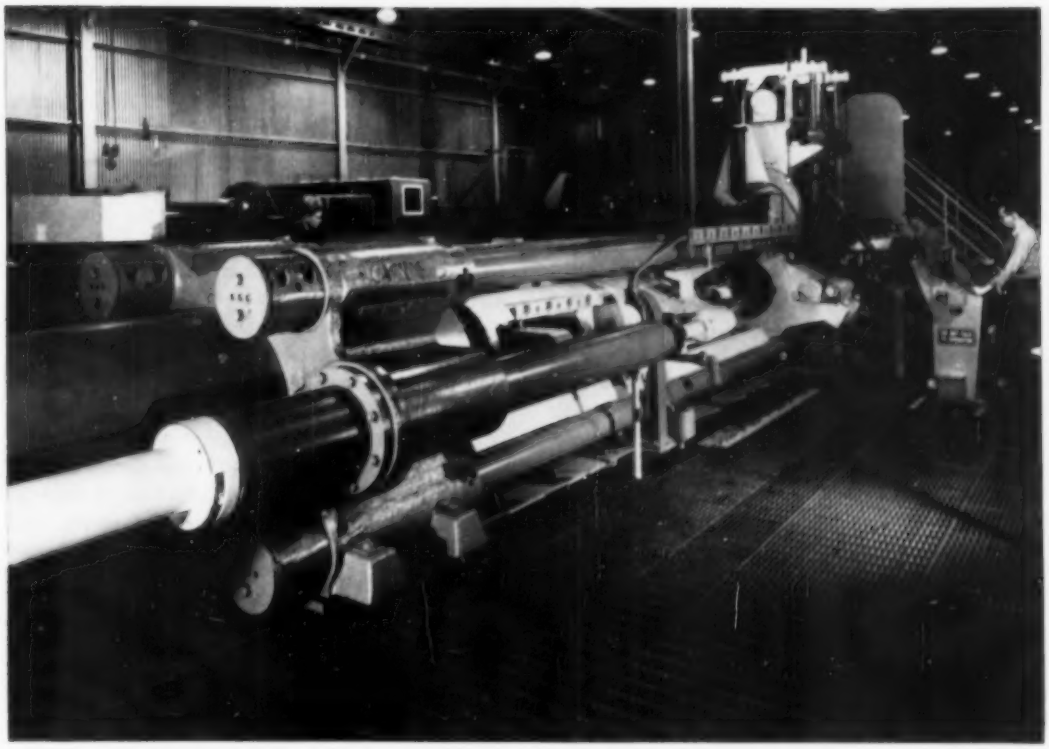
1. As already mentioned, the molten salt bath (barium chloride) has been and still is used in many plants. We use it for most of the work at Persan. Technically this method gives good results, but it is costly not only because of the high price of electric heat in Paris and its environs, but also because material handling is awkward with furnaces of this type, unless they are mechanized for high production as in certain American heat treating departments.

2. Some operators have tried induction heating.* High-frequency currents are usually used. These installations are satisfactory for aluminum and magnesium, for stainless steel and bearing steels, but low-frequency current seems to be preferable for reheating between piercing and extrusion. Heating of plain steel billets from room temperature to extrusion temperature with a low-frequency induction furnace has been tried with encouraging results and is now done commercially in the United States. Induction heating, nevertheless, has certain inherent disadvantages: It is economic only where electricity is relatively cheap; it requires a considerable investment in electrical transformers and controls; its rapidity renders some fragile metals susceptible to damage from thermal shock, and finally it is not amenable to precise temperature control. A partial solution to the last two disadvantages can be attained by heating in successive stages, but this increases the time in the heating coil as well as the number of coils necessary to produce the same hourly tonnage (which raises the investment). On the other hand, induction heating has definite advantages. Labor costs are low and the process can be completely automatic. Further, there are no costs for energy during downtime, as opposed to standard furnaces where temperatures must be maintained even if on low burners. These features indicate that induction heating will be more popular in America than in Europe.

3. A third solution to the heating problem is the "Balestra" process being used by our Italian licensee, La Fiav Mazzacchera. It uses a barrel-shaped furnace rotating on its horizontal axis, wherein the billets roll in a bath of molten glass. This not only prevents oxidation, but also descales any oxide that was charged on the billets. A characteristic of this process is that a surplus of glass usually sticks to the billet and this must be scraped off before the piece enters the chamber of the extrusion press. Material handling is an important problem which has interfered with the development of the Balestra process. Up to now its use has been limited to presses of low capacity. Still, the process requires only a small investment, and it uses cheap heat — either gas or oil. Its reliance on hand labor makes it of more interest to Europeans than to Americans.

4. Closely akin to the above is the method of coating a billet with a vitreous layer similar to enamel before putting it into a conventional heating furnace. The metal can then be heated to extrusion temperature without oxidation. This idea is still in the experimental stage for ordinary carbon steels although it is used industrially for stainless steel and seems to give good

*See particularly the four articles concerning induction heating of forging billets starting on p. 91 of *Metal Progress* for December 1954.



1000-Ton Horizontal Hydraulic Press at Jones & Laughlin Steel Corp.'s New Extrusion Plant

results. Its obvious advantage is that it uses standard furnaces.

5. Lastly, there is controlled atmosphere heating. At present it is an expensive method in itself, but recent developments make one hopeful that it will be a possible solution for the heating problem in extrusion plants in the near future.

Important Subsidiary Details

These comments show that the heating problem is not purely a technical one but involves a consideration of the extruded product and the general economic background of the particular country or even region. From a technical standpoint alone the heating problem must be solved to make extrusion competitive to blooming and rolling. Yet it would be a mistake to hold that the future of steel extrusion is completely dependent on the economic solution of the heating — or lubrication — problem. As always, the success of a technique depends upon the perfection of a number of details. For example:

1. Tools have been redesigned completely with a view toward improving extrusion time and surface quality.

2. Extrusion speeds have been increased to minimize heating of ram, lining and die.

3. Reducing the pressure by efficient glass lubrication permits the extrusion of longer billets, and this requires presses of given capacity having longer containers.

4. The necessity for lowering costs has led to a close study of the extrusion cycle, and this in turn to certain modifications in the press itself such as the methods of securing the tools. A special press for the extrusion of steel, different from presses used for extruding nonferrous metals, is rapidly evolving.

5. Billets must be meticulously cleaned to obtain the best surface quality on the product and cut down on butt scrap. This follows directly from the above-mentioned fact that the skin of the glass-lubricated billet forms the skin of the finished product.

6. The metal yield is very high and oftentimes better than that obtained by more conventional shaping processes.

New Markets for Extrusions

Extrusion with glass lubricants will open up new markets. These can be guessed from the nature of the process itself.

Since deformation takes place under hydrostatic pressure, possibility of fracture, either external or internal, is greatly minimized. Extrusion with glass should be ideally adapted to produce steels and other metals reputedly difficult to hot work – such as alloy constructional steels, refractory chromium steels and irons ranging from 5% to 30% chromium, stainless steels (such as 18-8 and 25-20), the "super refractory" metals such as "Nimonic" and the other alloys for jet engine blades which must be strong and stiff at 1500° F. or higher – not to mention the "newer" metals for atomic energy (uranium and zirconium) as well as titanium and molybdenum. The process is a perfect answer to the problem of handling certain rough cast metals. Nimonic ingots are broken down successfully by glass extrusion in America and England.*

It has been mentioned that extrusion of tubes with glass lubricant presents no greater problems than extrusion of solid rods. On the other hand, manufacture of steel tube by piercing and rolling is such a touch-and-go process that material control is a major problem. Glass extrusion is a much more economical procedure for making stainless steel tubes than conventional methods, as in a Mannesmann mill. In particular, thinner walls and better surfaces can be produced. Undoubtedly as experience increases it will become more economical to extrude steels with lower alloy content into a tube.

Since the die is a relatively cheap tool and can be changed without long delay, extrusion will be well suited to the manufacture of small orders. Not only is expensive downtime for tool changes minimized, but the small tool cost is readily amortized. Even when extrusion appears more expensive than rolling, there undoubtedly will be times when small orders should be extruded so the rolling mills can continue on the more important long runs. Each mill will find the proper balance here.

Extrusion will obviously exploit the market for odd shapes, such as channels, bulb beams, finned tubes and special cross sections. This has been discussed in detail by S. O. Evans in *Metal Progress* for April 1955.

Removal of the glass lubricant does not involve any special difficulties. It is done at Persan and at some of our licensees' plants by pickling in a mixture of hydrosulphuric and hydrofluoric acids or in molten soda. It can also be done by shot-blasting.

The improved surface quality of the extruded tube has opened up important markets. Sometimes the surface, even without grinding, has sufficiently high quality to give unexpected advantages – as for example in items going into atomic reactors where a glossy surface is desired to avoid all risk of contamination by lodgment of dust or other foreign bodies.

Another interesting development of the process arises in small countries whose internal consumption of tubes, profiles and special shapes is not nearly large enough to justify the installation of conventional hot working equipment. An extrusion press is almost a universal metalworking machine; it can manufacture solid bars as well as tubes, plain steels, special steels, and nonferrous metals and alloys. The combined tonnages of all these potential products can frequently justify the installation of extruding equipment.

It might be asked whether the experience gained in the extrusion of steel with glass lubricants will ever redound to the benefit of the nonferrous industry. Obviously, special glasses, softening at low temperature, can be prepared and used to advantage in the extrusion of certain bronzes, light alloys, or "new" metals. Advantages to be obtained would vary with the metal at hand. Light alloys are now extruded at slow speeds – on the order of a few feet a minute. Lubricating with glass can raise this figure forty-fold?

Some of the bronzes extruded by standard techniques have poor surface quality; others cannot even be extruded. Glass lubricant promises great improvements in this field. By extruding copper with glass lubrication, temperatures can be dropped to 1100° F., and this opens up the possibility of making thin-walled tubes without the necessity of multiple rollings and cold drawings. The low extruding temperatures when glass is a lubricant offer real advantages in making uranium shapes at temperatures below allotropic transformations that render uranium difficult to work. In addition, in all these examples lubrication lowers frictional losses, thereby increasing production through either greater speeds or longer billets.

This brief discussion of a process still in its infancy and still undergoing evolution should suffice to show the wide diversity of the field and the eventual possibilities.

*Heating in glass should also be of great advantage when handling metals like titanium which, when hot, absorb the common atmospheric gases, much to their detriment.

Powder Metallurgy in Japan

By TAKASHI KIMURA
*and HENRY H. HAUSNER**

The Japanese industry has a historic foundation in two decades of work with superior magnetic materials. Carbide tools, porous bearings and electrical contacts are now produced in volume. Intensive scientific investigation and widespread industrial interest are responsible for a steady growth in manufacture of small machine parts. (H general)

POWDER METALLURGY is a rather new industry in Japan, but is developing rapidly as it is everywhere else in the world. During the last few years production has grown considerably faster than research activities in powder metallurgy, although fundamental work in this field also gets much attention.

It may not be well known outside Japan that this country has an honorable tradition in powder metallurgy. More than a thousand years ago the famous Japanese sword, the "Katana," was fabricated from reduced iron powder gained from the iron-titanium sand on a Japanese beach. Modern powder metallurgy started in 1917, when the late Kotaro Honda, revered father of metallurgy in Japan and honorary member of the American Society for Metals, investigated the magnetization of iron powders and formulated the well-known Honda magnets containing nickel, aluminum, cobalt and titanium. Similar magnets, the Mishima magnets, were also fabricated later by powder metallurgy methods.

As in many other countries, powder metallurgy did not play an important role in Japan before World War II. Some bearings, some sintered carbides for tooling purposes, and some electrical contacts were fabricated on a small scale, but few other products were investigated.

At a late stage of World War II work on iron shell bands began in several laboratories. This development had started considerably earlier in Germany where it resulted in a large-scale production of iron shell bands for the German army. In Japan, work with this war product was somewhat parallel to that in the United States; in both countries there was a relatively late start and practically no production during the war years.

*Mr. Kimura is connected with the Japanese Telephone Co. (Tokyo) and has been in America during 1955 on a Fullbright Fellowship. Mr. Hausner is now general manager, Nuclear Engineering Division, Penn-Texas Corp., New York.

Many data in this report are taken from an unpublished study by K. Motoda of the Ministry of Commerce and Industry, Bureau of Heavy Industry, Tokyo, and the authors wish to thank him and the many Japanese powder metallurgists on whose publications this paper is based.

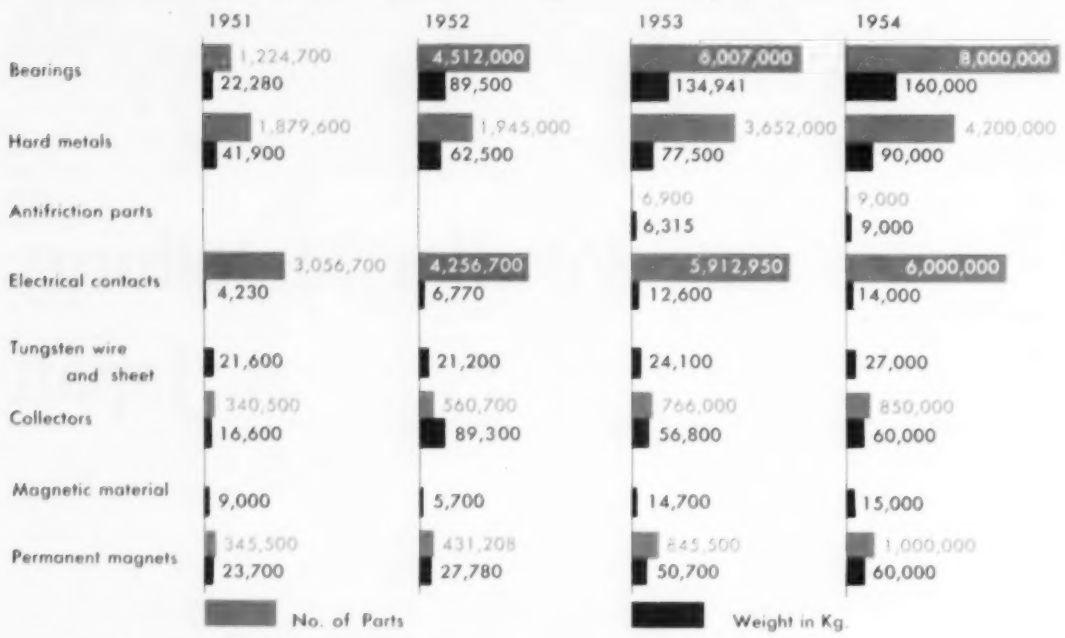


Fig. 1 – Annual Output of Several Powder Metallurgy Products in Japan, 1951 to 1954

After World War II the whole Japanese metalworking industry became interested in powder metallurgy. The universities also started research work on metal powders and investigations on the mechanisms of compacting and sintering. Notable among these are Osaka University in Osaka (Prof. T. Matsukawa), Naniwa University in Osaka (Prof. E. Shinba), Ehime University in Shikoku (Prof. H. Koto), Kyoto University in Kyoto (Prof. K. Iwase and Prof. K. Ogawa), the Research Institute for Iron, Steel and Other Metals (Prof. Y. Masuda), the Research Institute for Scientific Measurements (Prof. H. Kojima), Tohoku University in Sendai, Waseda University in Tokyo (Prof. S. Wakabayashi), Tokyo University in Tokyo (Prof. M. Sugiyama and Prof. Z. Hara).

Following in the tradition of Professor Honda, many experimental efforts were continued toward the development of magnetic materials. For instance, Akinori Takasaki's "Studies in the Sintering of Metallic Powders of the Iron Family", in which he described the magnetic properties of materials as affected by the sintering atmosphere and other processing variables, is to be mentioned. The kinetics of sintering has been extensively studied by Yoshimichi Masuda and co-workers; the fundamentals of mechanical comminution of metals investigated by T. Okamura and K. Inagati of Tohoku University. T. Matsukawa studied the preparation of coated and porous powders and devised a new porous bronze bearing.

The literature on powder metallurgy published by Japanese universities is increasing in quantity and is of high standard. University laboratories usually publish in the Japanese language (but frequently also in English) and the exchange of ideas between Japan, the United States and Europe has greatly improved during the last few years. The publications of the Japanese Institute of Metals, such as Iwase and Ogawa's investigations on the effect of oxidation and reduction of metal powders on the sintering process, should also be mentioned in this connection.

Also increasing in value are the publications of the Government Industrial Research Institute in Nagoya (Etsuro Hayashi, Gentaro Matsumara, K. Ishida and co-workers). The continuous survey of the sintering process by electrical resistivity measurements, proposed by Takashi Kimura and co-workers, and the same author's studies on the powder metallurgy of germanium, are well known to specialists in this field all over the world and are included in college courses in the United States. (This article of course makes no effort to review the

Table I – Consumption of Metal Powder in Japan, 1953
Units in kilograms (1 kg. = 2.205 lb.)

Classification	Iron	Copper	Graphite	Tungsten	Lead	Tin	Others
Bearings and filters	49,498	69,170	1,950	—	1,104	6,826	278 Zn
Hard metal alloys	—	—	3,555	83,336	—	—	5,395 Co
Antifriction material	—	71	8	—	11	7	—
Other mechanical parts	5,912	—	—	—	—	—	—
Electrical contacts	—	1,984	—	6,278	—	—	1,317 Ag
Lamp and electronic tube material	—	—	—	25,720	—	—	14,941 Mo
Electrical collectors and brushes	2,257	42,134	4,237	—	40	4,593	—
Total*	57,667	113,359	9,750	115,334	1,155	11,426	

*Other than for magnetic materials.

Japanese literature on the subject, but the above citations are presented to show that powder metallurgy research in Japan is growing and is of importance.)

Production Data

As remarked at the outset, powder metallurgy has developed into one of the most progressive industries in postwar Japan. It has received especial attention from many manufacturers of small parts, especially on account of its economical, low-cost fabrication. The annual value of the present production in Japan is approximately 3,200,000,000 yen ($90,000,000), or approximately 0.3% of the value of the total machinery industry production. A survey of the Japanese Bureau of Heavy Industry determined that as of October 1954 more than 50 manufacturers were using powder metallurgy methods, in which were employed 580 technically trained persons and approximately 2000 workers, roughly two-thirds male and one-third female.

With respect to equipment, Japan is quite independent of foreign countries. Hydraulic presses are used for most of the compacting operations; mechanical presses to a much smaller degree. Types and sizes are as tabulated below. Practically all of them were built in Japan.

Compacting Presses in Use in Japan

Cold compacting, hydraulic	
Over 100 tons	53*
40 to 100 tons	46
Under 40 tons	75
Cold compacting, mechanical	
Over 40 tons	11†
10 to 40 tons	12†
Under 10 tons	48
Hot compacting	
Over 40 tons	3
10 to 40 tons	4
Under 10 tons	8

*Three of these were imported.
†One of these was imported.

Electric furnaces are predominantly used for sintering. Some 337 are of muffle type, exterior wound; in 184 the compacts are heated by direct radiation from the resistors. Only 37 furnaces fall outside these two categories. All these furnaces are Japanese made.

Consumption of powders in Japan in 1953 is listed, metal by metal, in Table I, except the amounts used in magnetic materials. The most important single metal is tungsten, used for sintered carbide tools and for the lamp and electronics industries. Copper powder is used in large amounts, mostly in the electrical industry for bearings and collectors or brushes for small motors and generators. The table shows further that iron powder metallurgy is still in its infancy, that iron powder is mostly used for bearings and very little in machine parts. It is expected, however, that fabrication of small precise parts by this process will grow rapidly within the next few years. There are indications also that the fabrication of electrical contacts by powder metallurgy may grow in the near future.

The growth of the Japanese industry during the period from 1951 to 1954 is shown in Fig. 1. The healthy increase is not only due to the low cost of powder metallurgical products, but also to the fundamental work in the research laboratories which gave us a much better understanding of powder metallurgy as a fabrication method.

Among the powder metallurgy industries in Japan are several larger ones, such as Tokyo Shibaura Electric Co., the Tungaloy Mfg. Co. and the Mitsubishi Metals and Mining Co. in Tokyo, Tohoku Metal Industries in Sendai, and Sumitomo Electric Industries, Ltd. in Osaka.

Some of these fabricate just one powder metallurgy powder, others produce several. The largest fabricator of tungsten is Tokyo Shibaura Electric Co.

For example, Sumitomo Electric produces two to three tons per month of hard metals for tooling purposes, one ton of bearings and filters, and only 300 to 500 kg. of contact materials. Other heavier parts are under study. It sould be mentioned that this company has 20 years' experience in the fabrication of hard metals, and that some of the work occupies air-conditioned factory rooms.

At the present time many smaller Japanese firms are considering powder metallurgy as a manufacturing method. Some of the existing fabricators operate as licensees of American and European companies and work in close cooperation with them.

The Japanese powder metallurgists meet reg-

Metals of High Purity

*By J. C. CHASTON**

We have now five chemical and six thermal methods for driving solid and gaseous impurities down to low amounts. Each is briefly discussed, and purity of the various metals refined by these methods is tabulated. (C general)

THE ACHIEVEMENTS of the past decade in producing the semiconductors germanium and silicon in a state (by present-day reckoning) of very high purity are well known, but the advances made in producing other metals free from all but traces of impurities have, perhaps, received less attention.

Progress has been such, however, that it is becoming increasingly evident that the older methods of denoting purity "in terms of nines"—99.99% and so forth—are already inadequate. In the field of "pure" metals, we have reached the era when we think of impurities in terms of parts per million and it is high time that we acquired the habit of expressing the purity of metals accordingly. Many metals are now available with a total impurity count of less than 100 ppm. (99.99%)—and some have as little as 5 ppm. total, with less than 0.05 ppm. of specific impurity elements.

There are two fundamentally different approaches to the problem of making metals of high purity. On the one hand, a very pure compound of the metal may be prepared by chemical and physico-chemical operations, and this may then be reduced directly to the metal under carefully controlled conditions. Alternatively, the metal of commerce may be refined by modifications of the classical methods of process metallurgy as well as by such new operations as zone refining. Of course, the two general methods may be combined; a metal produced initially in as pure a state as possible may be subjected to further refining treatments. The exact method to be adopted for any particular metal will depend on the characteristics of the metal and its compounds, and may often be determined by the susceptibility of these to contamination during processing.

The basic procedures available for producing a pure metallic compound ready for reduction to metal are all well know and include:

1. Repeated precipitation of an insoluble compound. This is a standard procedure in chemical

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ularly in a group called the Japanese Powder Metallurgy Technical Association, whose chairman now is Prof. K. Iwase. The addresses and discussions during these meetings result in a close contact between the members. The association also publishes a magazine called *Powder and Powder Metallurgy*.

In summary, it might appear that, contrary to the usual European and American assumption that low labor rates are the dominant factors in Japanese productivity, the electrical industry and many branches of the machinery industry are giving close attention to the economics of powder metallurgical methods, and a healthy growth in number and variety of applications is to be observed. All this is in addition to a sound industry based on those things which powder metallurgy is uniquely able to produce, such as porous bearings, hard metals, and some magnetic alloys.

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analysis, but is subject to limitations due to absorption and co-precipitation of impurities.

2. Repeated recrystallization.

3. Precipitation of impurities as insoluble compounds—often assisted by simultaneous precipitation of an impurity deliberately introduced to act as a carrier or collector.

4. Fractional distillation.

5. Solvent extraction.

6. Ion exchange processes.

Chemical Processes—Exact details of the procedure will, of course, vary from metal to metal, but in all chemical methods of purification two major limitations are encountered. The most important of these is contamination from reagents and this is particularly serious when large volumes are employed. It often becomes necessary to spend more time on purifying reagents than on making the final product! Certain reagents are particularly troublesome as sources of impurities; for example, whenever caustic soda is employed it is almost inevitable that some silica will be introduced into the product.

A second source of contamination is from the reaction vessels. Boron, silicon and alkalis may all be picked up from glassware and silica. Contamination from containers may sometimes be minimized by a sufficiently long "conditioning" treatment with appropriate solutions which dissolve traces of impurities from the surface.

Having produced as pure a compound as possible, the final stage of reduction to metal is carried out by some such process as treatment in hydrogen at high temperatures. Here the main source of anxiety is to avoid contamination by impurities derived from the trays in which the compound is heated. The final consolidation may be by powder metallurgy processes (to avoid danger of contamination during melting) or by some such process as argon-arc melting.

A considerable measure of success has been attained in recent years in producing metals of high purity by various chemical programs. Table I endeavors to indicate the degree of purity in terms of parts per million of total residual impurities which can now be achieved for a number of metals.

Thermal Processes—The second method of approach to pure metals, that of refining a crude or commercially pure metal, may also be considered to involve one or more basic procedures, the chief of which are:

1. The traditional fire-refining method of oxidizing impurities in a molten bath and fluxing these away.

2. Fractional distillation.

3. Van Arkel or iodide distillation process.

4. Electrolysis.

5. Zone melting.

6. Vacuum melting.

It may be of interest to consider some of the outstanding characteristics of these methods. The traditional method of refining and fluxing is, in general, suitable only for removing major quantities of impurities. It is obvious that in order to remove the last traces of impurities in this method it is necessary to maintain a very high concentration of oxygen in the metal. Perhaps the only two metals that can be refined to any really high degree of purity by these methods are silver and gold. It may be noted, however, that the product of a modern lead refinery is among the purest of all commercially produced metals, and this high state of purity is achieved essentially by a series of oxidizing operations.

Fractional distillation, the second of the above list, is also a process employed on a very large

Table I – Metals Reduced From Compounds Purified by Various Methods
Metallic Impurities in Parts per Million

Repeated Precipitation	Repeated Crystallization or Ion Exchange	Precipitation of Impurities	Fractional Distillation	Solvent Extraction
Ag 10	La 20	Co 10 100*	Ge 0.1	Ga 50
	Ce 20	Fe 10 100*	Si 0.5	
	Nd 30	Ni 10 100*		
	Y 30	Pt 10 10*		
		Pd 10 10*		

*Gases (O + H + N) in ppm.

scale to produce high-purity zinc, magnesium, cadmium and mercury. Zinc made by fractional distillation may contain as little as 10 ppm. of total impurities, and it is possible to reduce the total impurity content in mercury to 5 ppm. or even less. Vacuum distillation is the main process used for purifying the alkali metals lithium, calcium, sodium and potassium; the chief difficulty is in the choice of a suitable container for the liquid metal and its vapor.

The Van Arkel or iodide process may be regarded as a process of selective distillation. Crude metal in the outer zone of the reaction chamber is attacked by iodine vapor and the pure iodide is transported across the evacuated space and decomposed on a heated filament. By the Van Arkel process it is possible to obtain very pure titanium, zirconium, chromium, hafnium and thorium, and the process is particularly valuable for removing oxygen, hydrogen and nitrogen. It is less efficient as a means of eliminating the last traces of metallic impurities and silicon.

Electrolysis has been used on a large commercial scale for many years as a means of purifying impure or bessemerized copper. Electrolytic iron is also commercial. In the production of very pure metals it is usual to re-refine two or more times, using progressively purer electrolytes at each stage. The three-layer process for refining aluminum is well known and is capable of producing aluminum with a total impurity content of perhaps 30 ppm.

The newest of all the processes for refining metals is zone melting, which has received considerable attention since its successful production of very pure germanium. The method has more recently been applied to the purification of silicon, and it is understood that attempts are now being made to purify bismuth, antimony and tellurium by zone melting. The general principles have been described so often in recent months that they need not be referred to further here. It may be emphasized, however, that zone melting is obviously only of value in certain limited applications and that it will not automatically remove all impurities from any metal.

One of the limitations of zone melting (and indeed of other methods of refining which involve melting) is that the container is a potential source of impurities. One method of overcoming this difficulty is the "cage zone refining" method recently suggested by Westinghouse Electric Corp. in which the sample is ribbed and the heating arrangements so adjusted that a shell of solid metal remains unmelted and supports the molten center.

A disadvantage of all the refining processes discussed so far is that none of them remove oxygen, nitrogen and hydrogen, which in many instances are the really troublesome impurities. When it is important to remove these gases, the obvious process is vacuum melting. The difficulty here is that once a metal is melted in a refractory crucible, some contamination from the refractory is almost inevitable. It is not always appreciated, moreover, that this contamination is always greater when operating in a vacuum than in air. As a consequence, considerable attention has been given recently to techniques in which metal is melted on a water-cooled copper hearth instead of in a refractory crucible. Usually such vacuum arc melting furnaces use consumable electrodes. The problem becomes more difficult when an arc from a non-consumable electrode furnishes the heat, but the process is possible particularly if sufficient power is available to force the current across the arc gap.

How Pure Is Pure?—Table II summarizes the purities which have been achieved for various metals by the thermal methods. If these figures as well as those in Table I are accepted, it will be seen that the purest metals that can be produced at the present time all contain between about 5 and 500 ppm. of impurities. This is,

Table II – Metals Purified by Various Refining Methods
Metallic Impurities in Parts per Million

Oxidation and Fluxing	Fractional Distillation	Van Arkel (Iodide) Process	Electrolysis	Zone Melting	Vacuum Melting
Ag 10	Cd 10	Cr 200 50*	Al 30	Al —	Cu 10 10*
Au 10	Hg 5	Hf 130 50*	Cu 10	Bi —	Fe 10 10*
Pb 30	Mg 50	Th — 50*	Fe 10	Ga —	Ni 10 10*
	Zn 10	Ti — 50*	Cr 50	Ge 0.1	
	Ca 10	Zr — 50*		In —	
	K 10			Sb —	
	Li 10			Si 0.1	
	Na 10			Te —	

*Gases (O + H + N) in ppm.

of course, a considerable advance over the 99.9% pure metal which was, and often still is, regarded as acceptable. But, from the physicist's point of view in particular, a metal with even 1 ppm. of impurities is extremely impure. In a cubic centimeter of a metal of this purity, for instance, as many as 10^{16} impurity atoms would then be distributed among the 10^{22} atoms which are present. It is sometimes useful to consider, moreover, that in a cubic array of atoms, 1 atom in every 100 encountered on proceeding along any axis will be an impurity atom in such a "pure" metal. Today we may talk of impurities in metals in terms of parts per million; it is evident that in the years to come we may look forward to a time when the impurity content of a metal is counted in millionths of a part per million.

Utility—In any review such as this it is pertinent to ask "what is the use of a pure metal?"

One method of answering this question is to attempt to determine the driving force behind the efforts now being put into the production of these materials. Undoubtedly the main driving force comes now from the electronics industry. For improved rectifiers and such devices as transistors, electrical engineers need semiconductor materials such as germanium and silicon in which the impurity atoms are held at a very low and controlled level. The performance of these devices, in fact, is entirely dependent on the special characteristics which materials having a low and controlled impurity content exhibit.

It seems very likely, however, that electrical and magnetic characteristics may not be the only ones which are likely to be modified profoundly by the reduction of impurity level to very low values. Theoretically, the strength of a metal probably depends—in the limit—on the configuration of a few atoms in the neighborhood of dislocations and lattice irregularities. It follows, therefore, that if a metal is sufficiently pure to be significantly free from lattice defects, quite disproportionately large changes in the mechanical properties might be secured.

To be more specific, it does not seem too much to hope that the general limit of impurity level may be reduced at least by a factor of ten during the next decade. It is already evident, however, that if much further progress is to be made, it will be necessary to develop new methods for measuring the impurity contents. Already the lower limit of detection by spectrographic methods has been reached for many materials. Colorimetric and similar methods are likewise generally unable to detect much less than 1 ppm. of many important impurity elements. For that reason our appraisal of purity in metals depends greatly upon the accuracy and sensitivity of the analytical methods currently available.

It is almost certain that the new methods which will be evolved will have a physical basis. One very obvious method is to use radioactive tracers, but some attention is also being given to the possibility of using measurements of electrical resistivity at temperatures near absolute zero as a measure of impurity content.

In conclusion, it may be emphasized that the attempt to produce various metals of higher and higher degrees of purity is no vain pursuit of an academic abstraction. Knowledge about pure metals is basic to any true science of metals. And greater knowledge inevitably leads to new uses. Important applications in communication and electronics industries have already been made. Further industrial uses of some of the purer metals which have recently become available may well depend on the ability to produce them with full control of the levels of metallic and gaseous impurities on a tonnage basis.

Training of Technical and Scientific Manpower in the U.S.S.R.

*By N. H. POLAKOWSKI**

THE METHODS employed and the results achieved by Russia in training its engineers and scientists have recently received considerable attention in the American press and the subject has been debated from various angles in both the technical and nontechnical press. However, these articles have given general information rather than satisfying the professional curiosity of a specific category of technical men. It will be the purpose of this one to bring out and emphasize such aspects as may be of particular interest to metal engineers and educators.

This article is based on materials extracted from various sources ranging from the official Great Soviet Encyclopaedia to Russian and satellite periodicals. Of a number of pamphlets and brochures published by various Soviet propaganda agencies only one or two proved of value. Some of the detailed information was obtained from an article published in February 1954, in the East-German *Metallurgie und Giessereitechnik* by A. Kuentscher. The author, on the staff of Freiburg Mining Academy in Saxony, gave a first-hand account of his visit to some of the Soviet metallurgical institutes and steel plants.

A general functional scheme of the Soviet educational system is sketched on p. 70.

It is not within the aim to give details of Soviet secondary education except for saying that, insofar as elementary science is concerned, a graduate of a full, 10-year, secondary school (location A on the chart) is probably better equipped than his American counterpart graduating from junior high school, but not as well as a holder of a British higher school certificate. Gold or silver medals are bestowed upon the two top ranking graduates – a practice which was universal in the Tsar's time and which was revived not so long ago by the present regime.

Since the number of candidates competing for entrance into institutions of higher learning has far exceeded the number of available places, students are usually accepted on the basis of competitive entrance examinations. Only medal-holders are normally exempted from this requirement and are admitted directly.

Graduates of secondary technical schools ("Technikums", position B on the chart) are admitted to a university only after spending at least three years on an industrial assignment. Again, the above restriction does not apply to gold and silver medallists.

Universities and Institutes

There are 31 universities in Russia which, from the viewpoint of organization, resemble the Central European type and do not provide any engineering courses. They correspond somewhat to liberal arts colleges in the American scheme of things, but the normal duration of studies in all departments is five years.

Higher technical education is provided by two types of schools:

1. The large polytechnic institutes offering a choice of all-round courses in most of the major branches of engineering, such as civil, electrical, mechanical and metallurgical. Here the possibilities for specialization are usually limited to a selection among a few elective subjects during the senior years.

2. Smaller specialty establishments, also termed "institutes", but adapted strictly to the needs of a particular industry. Thus, there are Institutes of Road Transport, Institutes of Agricultural Chemistry, Medicine, Mining, Textile Industry, and so on. These are in turn split up into faculties, sometimes up to five in number, which turn out future experts in specific lines.

The great majority of Soviet specialists come

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Counting his pre-college education, a Russian boy or girl can become an engineer for industry or for research in 15 years. If he reaches that goal via a technical high school it takes four years longer. There is strong competition for such opportunities, but self-criticism appearing in Soviet journals indicates that graduates are usually too highly specialized for jobs requiring a broad general background rather than detailed knowledge of a narrow field. (A 3)

from schools of the latter type (location C on the chart). Originally these institutes were run by the various Ministries for which they prepared personnel. However, since 1946 most of them were placed under the jurisdiction of a special Ministry of Higher Education which in turn was merged in the spring of 1953 with the newly formed Ministry of Culture.

After the 10-year secondary school (or the 11-year course leading to a technician's diploma, plus three years of shop training) it takes five years to get an engi- er's degree. In these five years the program provides 36 hr. per week of lectures and laboratory during all ten semesters. The first two years are almost entirely devoted to fundamental sciences like mathematics, physics, chemistry, or applied mechanics. Basic professional subjects are taught in the third and part of the fourth year, the course culminating in a number of special disciplines and a thesis.

The curricula of similar faculties in various schools are standardized, but despite this fact degrees obtained in certain institutes carry more prestige than others. In this respect, establishments which are authorized to accept and consider dissertations for doctorate have the highest rating, as will be described below under "Graduate Studies".

Metallurgical Institutes

Apart from the metallurgical departments in some of the larger polytechnics (Leningrad, Sverdlovsk) there is a number of institutes specifically devoted to metals located in the principal metallurgical centers like Moscow, Dnepropetrovsk or Magnitogorsk. Some of these evolved from metallurgical faculties of the old mining institutes while others were built anew.

The Moscow Steel Institute, for instance, originated in 1930 from the metallurgical faculty of the old established Moscow School of Mines. At present it has three faculties:

1. Metallurgical, with specialization in blast furnace practice and steelmaking, electrometallurgy of steel and ferro-alloys, furnace design and controls and foundry practice.

2. Technological, with an emphasis on primary mechanical working, heat treatment procedures, and powder metallurgy.

3. Physico-chemical, where the main subjects are metal physics, physical chemistry of metallurgical processes and corrosion.

Only one out of five applicants is admitted to this institute where, incidentally, women represent one fifth of the student body. The school has a substantial staff headed by 30 professors, and has well-equipped laboratories.

Other metallurgical institutes are similarly subdivided. For example, the Kalinin Institute of Nonferrous Metals and Gold in Moscow, established in 1930, has the following five faculties – geology and prospecting, mining, metallurgy, technology, administrative and industrial engineering.

Many of the larger institutes also provide night schools and correspondence courses. There are also three special institutes for full-time employees of steel mills. In these the duration of a degree course is six years with 17 to 18 hr. of lectures and laboratory periods per week. In one of these institutes the percentage of female students was as high as 30%, a figure regarded as excessive by the teaching staff. (Imagine the number of women working on the mill floor in a steel plant!)

Graduate Studies and Advanced Degrees

There are no graduate schools in Russia of the type common in America. A holder of an initial degree can become a graduate student ("aspirant") by competitive examination in the

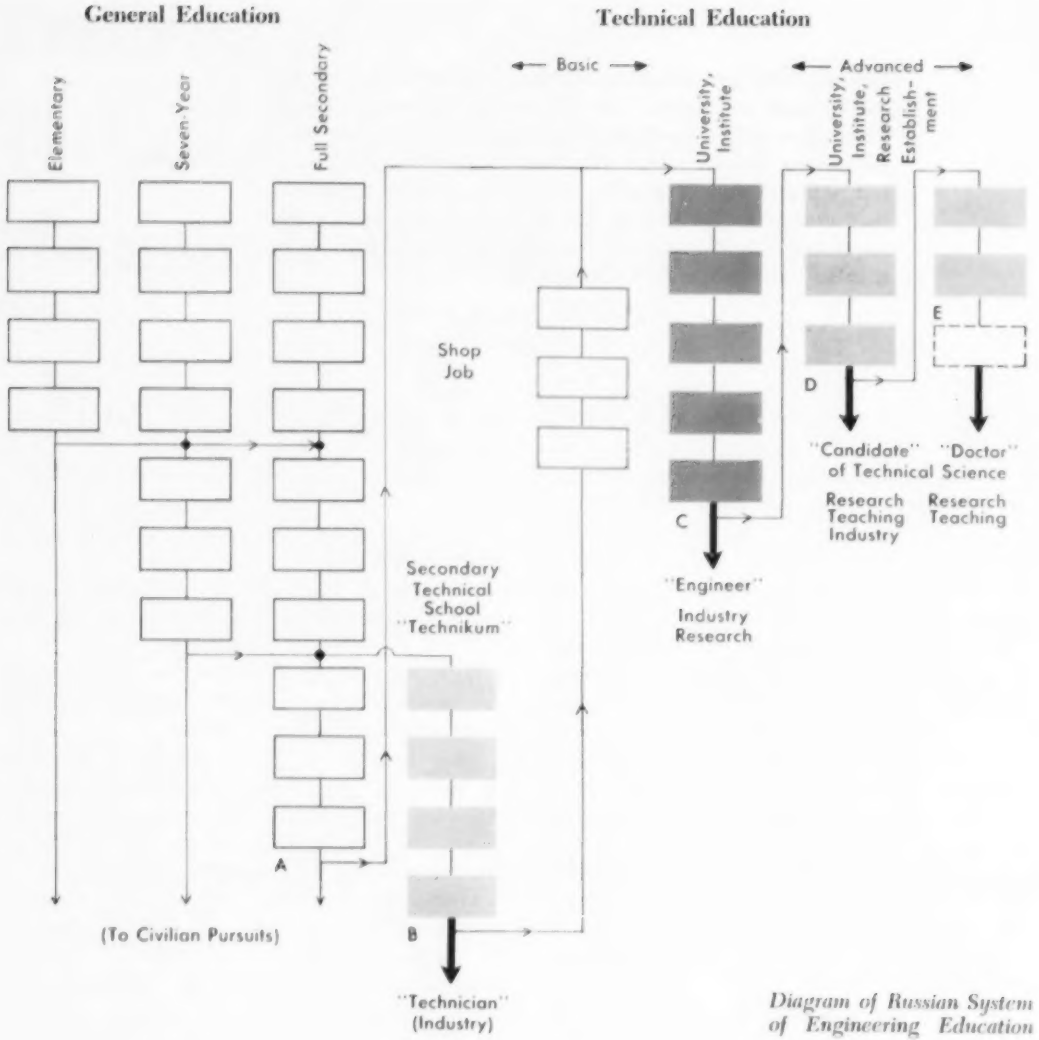


Diagram of Russian System of Engineering Education

subject in which he intends to specialize, one foreign language, and – not least – proficiency in political matters. Aspirants are attached to Chairs rather than departments. They attend no lectures (except seminars) and pass only one test during the three-year period provided to carry out preliminary studies, the experimental work, and write the thesis. The final examination is held in public and, apart from demonstrating competence in his main field of study and research, he also has to defend his dissertation against two opponents. (This is a common procedure in continental Europe.) If he is successful, the aspirant obtains the degree of "Candidate of Technical Sciences" (position D on the chart). His degree is substantially equivalent to our Ph.D. in America. In Russia a doctor's degree (position E) requires at least two additional years of thesis research.

As indicated earlier, not all the institutions are entitled to grant advanced degrees. Out of the 900 establishments for higher learning, a quarter of which are technical, only one third has this privilege. However, "Candidates" are also turned out by more than 200 industrial and scientific nonteaching research institutes, as illustrated by the advertisement reproduced alongside. In effect, then, there are about 500 institutions producing Soviet Ph.D.'s and about 160 sources of "full" Doctors of Technical Science.

In order to prevent laxity and "liberalism" from creeping into the degree-granting institutions, as well as to enforce uniform standards,

Future Miners Learning About Pneumatic Drills. (From Y. N. Medinsky's book, "Public Education in the U.S.S.R.")

a Higher Attestation Commission is active within the Ministry of Culture. All advanced degrees to be conferred by any institution are first submitted to this commission for approval and are invalid without it. It appears, however, that that body is primarily concerned with doctorate dissertations. In 1952 it vetoed 121 Candidate degrees (about 2.5% of all submitted for confirmation) and 65 doctorate degrees (13% of the total).

Selective Recruitment From Industry

Since early 1941, Soviet citizens have been deprived by decree of any possibility to change their jobs at will. As a rule, a man cannot leave his post without the specific consent of his employer; if he does, he is automatically liable to prosecution and sentencing to a stretch of "corrective labor" of not less than a year.

The law leaves, however, two exit possibilities of which one is particularly pertinent to the subject matter of this article. An employer is bound to give a paid leave of absence and traveling expense to any employee who has a university degree and wishes to attend an examination for admission to advanced or graduate study. Acceptance of the individual as an "aspirant" automatically terminates his previous employment.

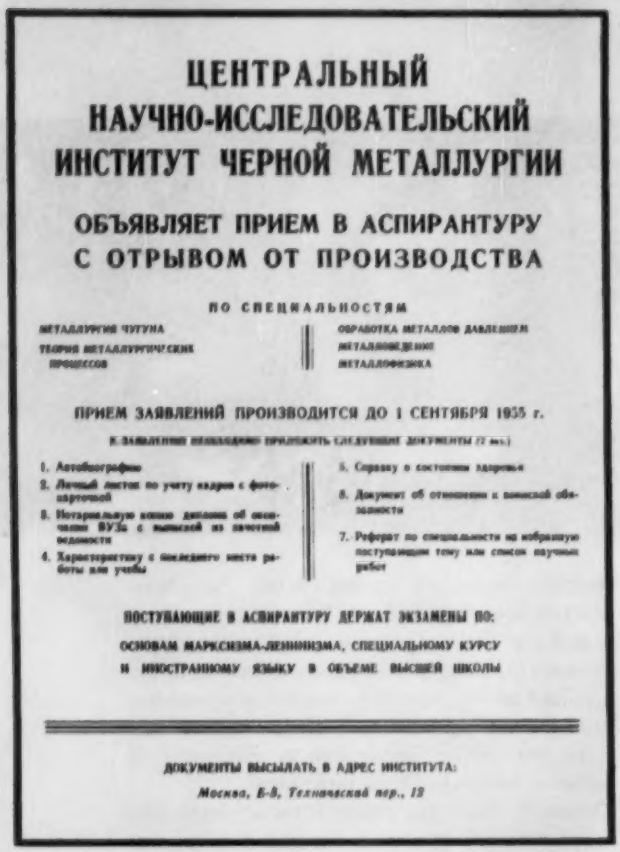
This system results in a steady influx into research establishments and advanced technical schools of men who frequently have had considerable practical experience before undertaking a three or five-year course of graduate work. Such people represent a valuable asset to the institutions they eventually join, by combining theoretical knowledge with down-to-earth engineering outlook.

The enormous appeal of an engineering or scientific career to Soviet youth has been variously interpreted by Western commentators. Some have dwelt upon the substantial salaries engineers are supposed to earn and the suburban villas and automobiles they receive as premiums. Social prestige and the fact that more than half of the top Soviet officialdom is composed of engineers have also been mentioned.

Naturally there are always some students who choose technology as a career because of genuine interest. However, economic considerations usually provide a very large, if not the most powerful, stimulus. From this angle, and under the particular conditions prevailing in the U.S.S.R., the engineer or the applied scientist is on the top of a small world. His average salary may be as high as $1500 per year; in exceptional cases it may reach the $3000 mark (these estimates being based on the actual purchasing power of the ruble). While these figures seem niggardly to Americans, such incomes place the technical professions well ahead of physicians and lawyers. As far as tradesmen are concerned, a carpenter would be lucky if he made $700 per year.

One also has to realize that the number of engineers who own automobiles or houses represents a minute proportion of the total, probably a fraction of one percent. But again, instances of this sort are widely and skillfully advertised, so that those who cannot reach this goal can at least afford a pleasant dream.

Holders of advanced degrees have the added opportunity of being eligible for positions in universities and research institutes, where not only are the salaries relatively high but also the work is congenial and the atmosphere is more relaxed than in industrial plants.



ЦЕНТРАЛЬНЫЙ
НАУЧНО-ИССЛЕДОВАТЕЛЬСКИЙ
ИНСТИТУТ ЧЕРНОЙ МЕТАЛЛУРГИИ

ОБЪЯВЛЯЕТ ПРИЕМ В АСПИРАНТУРУ
С ОТРЫВОМ ОТ ПРОИЗВОДСТВА

ПО СПЕЦИАЛЬНОСТЯМ

МЕТАЛЛУРГИЯ ЧУГУНА
ТЕОРИЯ МЕТАЛЛУРГИЧЕСКИХ ПРОЦЕССОВ
ОБРАБОТКА МЕТАЛЛОВ ДАВЛЕНИЕМ
МЕТАЛЛОВЕДЕНИЕ
МЕТАЛЛОФИЗИКА

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ПОСТУПАЮЩИЕ В АСПИРАНТУРУ ДЕРЖАТ ЭКЗАМЕНЫ ПО:

ОСНОВАМ МАРКСИЗМА-ЛЕНИНИЗМА, СПЕЦИАЛЬНОМУ КУРСУ
И ИНОСТРАННОМУ ЯЗЫКУ В ОБЪЕМЕ ВЫСШЕЙ ШКОЛЫ

ДОКУМЕНТЫ ВЫСЫЛАТЬ В АДРЕС ИНСТИТУТА:

Москва, Б-8, Технический пер., 13

Announcement by the Central Research Institute of Ferrous Metallurgy, Moscow, of Entrance Examinations for Graduate Studies in the Following – Pig Iron Making, Theory of Metallurgical Processes, Plastic Working of Metals, Metallography and Heat Treatment, Metal Physics. (Reproduced from Stal, *July 1955)*

Achievements and Problems

Obviously Russia has had notable success in building, in a relatively short period, an extensive training apparatus for mass production of technicians and scientists of all descriptions and calibers. That these men are of good quality can be judged not only from the notorious percentage statistics showing continuous industrial expansion but also from the emergence of such tangible articles as nuclear weapons and intercontinental bombers. However, as pointedly stated in D. Shimkin's article in *Mechanical Engineering*, August 1955, Soviet technical education is primarily designed to supply supervisors of manufacturing routine – and, it may be added, product engineers. As a result, many of the major technical developments on this side of the iron curtain make their appearance in Russia shortly thereafter.

From opinions expressed from time to time in the Russian press, the inference can be drawn that this deficiency of their engineering educational system is appreciated – at least in some quarters. These criticisms are mainly concerned with the teaching programs and textbooks now in use. The large number of narrowly specialized or splinter subjects which fill the curriculum is being attributed, not to a genuine concern with the students' needs, but to the necessity for staff members to fulfill the "norm", the minimum teaching load. It has also been pointed out that overburdening the student with a multitude of secondary details and a mass of factual data is likely to narrow his outlook and seriously impair his creative ability.

Textbooks—The most conspicuous feature of Soviet books which have been approved for university texts is their huge size. Yet upon examining them, the reader frequently finds a series of meticulous descriptions of phenomena, processes, and apparatus which appear to be only loosely interrelated, if at all. The over-all picture is often incoherent and the relation to fundamentals is not obvious.

Among metallurgical texts the 600-page "Openhearth Steelmaking" by Trubin and Oiks, as well as Okorokov's "Electric Steel Melting Furnaces" can be quoted as pertinent examples, if statements published in Soviet reviews can be believed. Another 600-pager by Pavlov, a corresponding member of the U.S.S.R. Academy of Science, dealing with the theory of plastic forming of metals, has been described by a group of four reviewers as completely ignorant! Their detailed analysis of the various nonsenses contained in this book ended with the rather straightforward remark that the text should never have been allowed to get into a student's hand.

Finally, a review which appeared in the April 1955 issue of *Works Laboratory (Zavodskaya Laboratoria)* of a recent book on high-temperature properties and tests, contains the following almost unbelievable statement:

"The author almost completely ignores foreign laboratory experience. On the one hand, this fact indicates the author's desire to bring out as fully as possible the achievements of Soviet investigators, but on the other it leads in many cases to a one-sided and an incomplete treatment of the problem."

Sheet-Metal Fabrication in Britain

(With Special Reference to Aluminum and Nickel Alloys)

*By TOM BISHOP**

Some aspects of industrial practices, especially finishing operations, wherein British firms excel (in the opinion of a visiting American Productivity Team). Stiff, high-temperature alloys are successfully formed with a soft metal punch which itself deforms into the shape best adapted to each intermediate stage. (G 1, Al, Ni)

BEFORE reviewing some recent important developments in the handling of sheet aluminum and nickel alloys, it might be remarked that many British companies in the pressed metal industry – in particular, the smaller organizations – are engaged in jobbing or batch production work, and therefore have to contend with comparatively small runs on any one job. This should be constantly borne in mind when reviewing the present setup, and may often be the reason why an American would observe certain techniques that would not be entertained in the average large shop in the U.S.A.

Some pressed metal factories in Britain are using obsolescent equipment; indeed, the American Productivity Team which toured Britain in 1951 reported that presses 30 years old were commonly used. But this situation is fast improving, and many firms are spending large sums on replacements for higher speed and increased accuracy. Double-action presses have been widely installed, while triple-action presses have also made their appearance.

The appearance of "Productivity Reports" by American (1953) and British (1950) teams, and a review by the British Productivity Council (1954), have done much to highlight the shortcomings. The industry is well served with up-to-date information by the Sheet and Strip Metal Users' Technical Association (SASMUTA) by periodic conferences and exhibitions, and by the trade organization, Sheet Metal Industries Association, and its official journal *Sheet Metal Industries*.

Tooling—Although it cannot be claimed that there have been any revolutionary changes in the general methods of manufacture and use of power presses and press tools in the postwar years, nevertheless there has been steady and noteworthy progress toward greater efficiency and lower costs. Some companies have introduced templet die tools designed to lower tool costs on certain components, while a number of alternative materials for toolsteels have been

*Editor, *Metal Treatment and Drop Forging*, London, England.

used on short runs. The increasing use of transfer presses and multistage or progressive tools, combined with automatic feed from coiled strip, has also stepped up production and reduced labor and handling.

Automatic finishing mechanism has been installed on a fairly extensive scale since the war. Pickling plants, requiring the attention of only one or two operators, are to be found in some of the larger factories, while at least one has installed semi-automatic spraying machinery. Others use the electrostatic spray method.

One of the features of the washing machine factory of Hoover Ltd. in South Wales is an automatic anodizing plant for aluminum tubs, lids and various other parts. It is fed by overhead conveyers from the production floors and the parts are loaded to their respective carriers or jigs on a special service conveyer for transfer to the first station.

Even as early as mid-1951 the American Productivity Team spoke highly of the general plating and polishing departments of works visited, stating that in this the British plants usually excelled their American counterparts. A common method of surface preparation is by phosphate coating before painting, either by immersion or by spray coating. One type of installation, I believe, not in use in America is the "Rotodip" process. In it, a complete automobile body shell with doors, hood and trunk is mounted on a "spit" riding a conveyer. The body shell continuously turns as the conveyer moves through cleaning, painting and drying.

The bodies are so engineered as to allow paint to flow into the body cavities and coat all inside surfaces without becoming trapped therein and causing "runs" after leaving the drying oven. This is an excellent means of providing a rust-preventive coating over the entire metal surface of the body and offers decided advantages over the method of priming the separate components and then spray painting the entire body after the final assembly.

Plastic Tooling

Plastic press tools are largely American in origin, but are certainly not being overlooked in Britain. Our techniques are not yet fixed upon any particular type of plastic material, and large-scale experiments are in progress using polyester or epoxy resins reinforced with woven glass fiber or asbestos, or phenolic-based plastics in the cast condition.

S. Matthews, who is with one of the largest motor-body producers, Briggs Motor Bodies, Ltd., has found the following methods most useful and reliable. Throughout this system of die manufacture reactive epoxide resins are exclusively used.

Core Mixture—20 parts by weight of epoxide resin plus catalyst to manufacturers' instructions; 100 parts silica sand or ground rock, 30 to 40 mesh, intimately mixed. For normal quantities, spade mixing in a metal tray is most satisfactory. (Cleaning of more elaborate equipment does present some difficulty.)

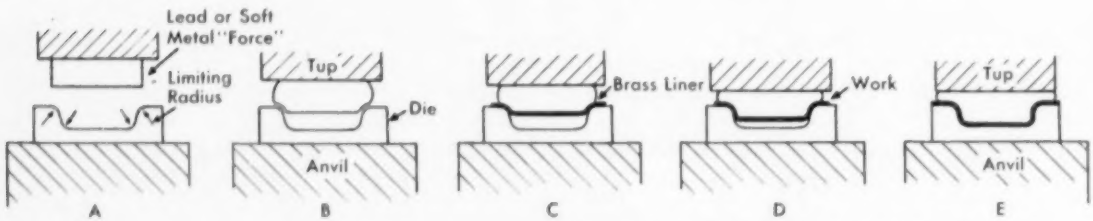


Fig. 1 – Stages in Pressing Stiff Sheet by Dyzacking
A – "Force" and die attached to tup and anvil
B – Preliminary forming of "force"
C – Brass sheet for thickness allowance
D – Working the component
E – Finish sizing

Facing Mixtures—100 parts by weight of aluminum silicate; 7 parts graphite; 100 parts epoxide resin plus catalyst as recommended. This is mixed in a conventional standard paint pressure-pot complete with mechanical agitator. After the ingredients are poured into the container the airtight cover is fixed and the agitator runs for 10 min. The pressure pot is then connected to a vacuum pump and stirring continued for 10 min. more at a reduced pressure of about 10 in. of mercury. The vacuum is gradually raised while stirring continuously for a total period of 45 min., whereupon the mixture is free from included air and ready for pouring.

It should be clearly understood that epoxide dies will not supersede metal dies but, costing less than a third of a conventional die, they will pay for themselves many times over.

"Dyzacking"—By this trade name goes a method patented by Mark Tyzack & Sons Ltd., which has been very successfully applied to stiff metal difficult to draw and to sintered aluminum powder sheet (S.A.P.) to be mentioned in the next section.

It utilizes a steel or cast iron bottom die with entrant and base radii larger than the limiting bend-radius of the material to be formed. The top die or punch is originally a block of lead alloy or other soft metal. In shop parlance it is called a "force".

As illustrated diagrammatically in Fig. 1A, the die and "force" are mounted, whereupon the soft metal is dropped or forced into the mouth of the impression of the die for a short distance (Fig. 1B). A piece of brass sheet of the same gage as the material to be worked is then placed over the die and further blows are delivered to shape the punch and at the same time provide a thickness allowance (Fig. 1C). The brass is removed and the workpieces are then pressed to the limit of this impression (Fig. 1D). The brass liner is then replaced and the punch forced into the die by a further series of blows, after which the run of blanks is re-worked to the limit of this second impression—and repeated in stages up to the contour of the required final impression (Fig. 1E).

This technique may sound a little tedious to the expert in the mass production of deep drawn parts in readily formable metals, but one of the advantages of Dyzacking is its rapid "getaway" for making prototypes and for relatively short runs. In fact, it is the only successful method so far developed for the cold fabrication of difficult materials like S.A.P. sheet, which apparently cannot be worked by conventional spinning and flow-turning in the cold.

Work in Aluminum

Sheet From Powder Metal—One of the most interesting developments in the past decade is the introduction of sintered aluminum powder products (S.A.P.) by the Swiss aluminum firm Société Anonyme pour l'Industrie de l'Aluminium. It has excellent corrosion resistance and remarkable properties at elevated temperatures, including stability and recovery of original full properties after prolonged heating and return to normal temperature. High Duty Alloys Ltd., has acquired the sole license for the manufacture and development of S.A.P. in the British Commonwealth, where it is marketed under the trade name of "Hiduminium 100".

This material in sheet form is almost impossible to cold form by conventional means. Its minimum bend radius is of the order of six times the thickness. However, the Dyzacking method has given excellent results.

In comparison with commercially pure titanium, "Hiduminium 100" sheet has higher proof stress at all temperatures up to 500° C. (925° F.) and higher ultimate strengths up to about 320° C. (600° F.) Furthermore, up to about 200° C. the ratio of Young's modulus to density is superior to that of titanium—a fact which is of particular interest to designers of supersonic aircraft.

Large Spinnings—The ultra-high-frequency television system in Switzerland, recently completed, has made extensive use of paraboloid reflectors, 12 ft. in diameter, spun from aluminum sheet by Precision Metal Spinnings Ltd. of Stratford-on-Avon. Metal is 2 S commercial purity sheet, half hard, 0.128 in. thick, with a tensile strength of 15,500 to 19,000 psi., 7% elongation, and bend test of ½ t. Circles are made of segments welded together, using a pure aluminum rod with gas shield, before the normal spinning process.

Building Sheet—An entirely new aluminum building sheet shown in Fig. 2 has recently been introduced by Northern Aluminium Co., Ltd. It is called "Snaprib" sheet from the simple, snap joint along the full length of overlapping corrugations. It is secured to purlins or studding by concealed clips, thus providing a continuous metal cladding which, with no holes or fixings exposed to the weather, is entirely leak-proof. Having the additional benefit of aluminum's resistance to corrosion, it requires no maintenance, and comprises a system that is of good appearance and suitable for the roofs of houses and for roofing and siding industrial buildings.

High-Nickel Alloy Sheet

Nimonic—The advent of aircraft gas turbines has brought sheet metal very much into the forefront as an engineering material (Fig. 3). The sheets most often specified in Britain for flame tubes and other hot parts are the "Nimonics", made by Mond Nickel Co., Ltd.—essentially high-nickel alloys with chromium, plus other hardening additions. The original Nimonic 75 (80-20 Ni-Cr, hardened with 0.5 Ti) has been found to be a good material for deep drawing and general fabrication, although fairly frequent interstage annealing (1920° F.) is usually required. The later Nimonic 80 (80-20

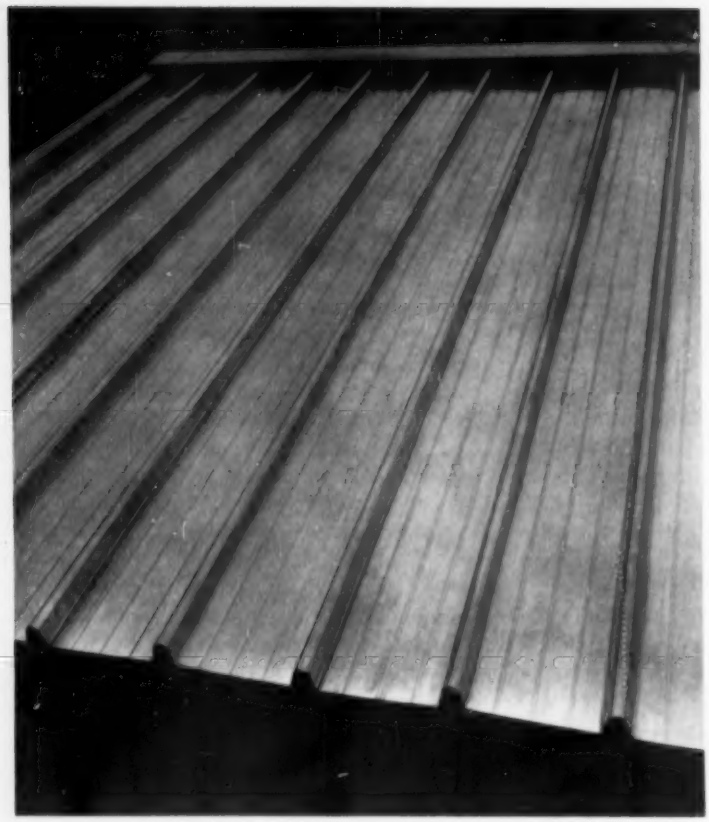


Fig. 2 – An Installation of "Snaprib" aluminum Sheet for Roofing and Siding of a Small Industrial Building

Ni-Cr hardened with 2% Ti and 1% Al) is considerably stiffer, with higher creep strength. Before cold working it must be annealed at 1825° F. and water quenched; after cold working it is given the solution and aging treatments. As might be expected, manipulation and fabrication difficulties are increased as creep resistance increases. Nevertheless, with sufficient care Nimonic 80 can be pressed to shallow depths, and the manufacturers are working on techniques which may allow deeper draws.

More recently, Nimonic 90 (60-20-20 Ni-Cr-Co hardened with 2% Ti and 1% Al) with even higher creep resistance at 1200 to 1500° F. has been produced in sheet form, but little practical experience has been obtained on forming this alloy. Laboratory work indicates that it will probably be no more difficult to work or weld than Nimonic 80, although its use is at present limited to simple shapes.

Nimoply—Perhaps one of the most interesting recent developments is a three-ply material known as "Nimoply", having a core of copper (for its high thermal conductivity) protected by outer layers of Nimonic 75. Its great virtue is that the copper core reduces temperature gradients and helps to eliminate hot spots, thus evening out thermal stresses, which is an important factor in obtaining increased life. Very little deep drawing has so far been done, but the ply material is sufficiently ductile for hand working.

So far one of the difficulties associated with three-ply materials is a sufficiently good bond over all the sheet. Deficient bonding in spots has led to opening up of the layers during hand rolling or pressing. If this problem of discontinuous bond can be solved, and accurate methods devised for proving its continuity, sandwich materials of this sort will be widely used in aircraft and high-temperature applications.

Equipment—For the deep drawing of Nimonics and stainless steels, one British company making gas turbine equipment, Joseph Lucas Ltd., found it necessary to install a new and special press (Fig. 4) designed and built by Foster, Yates and Thom Ltd. of Blackburn. It is of welded steel construction, hydraulically

operated and fully automatic. It is 40 ft. in over-all height and stands 32 ft. above ground, covering an area 12 × 8 ft. Its principal pressure of 1000 long tons is applied to the downstroke of the main slide, while 200 long tons is provided for the downstroke of the blankholder and 150 long tons on the die cushion. The main slide and blankholder may be linked together.

In this press a wide range of work is carried out from single reductions on 45-in. diameter blanks to 6-stage reductions on 54-in. blanks in s.w.g. from 21 to 14 (0.032 to 0.080 in.). Much of the available work is below the rated capacity of the press, but its size requires a large bed area.

Work of this type requires dies weighing up to 4 tons and lathes up to 60 in. diameter. In addition, due to the work hardening properties of the stainless steels and Nimonics, interstage annealing is frequently resorted to in a bell-type electric furnace.

One new application in the sheet metal field is the electric radiator made by Yelsen, Ltd. of Sidcup, England. A wire heating element of "Brightray C" (80-20 Ni-Cr produced by Henry Wiggin & Co. Ltd.) is insulated and sandwiched between two aluminum alloy corrugated pressings. The stranded wire has previously been stitched with glass thread to a sheet of compressed asbestos which contains a small proportion of rubber, and sandwiched between sheets of the same compound for insulation.

Since the insulating material is hygroscopic it is necessary to prevent absorption of moisture from the atmosphere during use – hence it is sealed between two sheets of aluminum alloy as mentioned above, and the whole assembly corrugated in a press to provide rigidity. Good heat transfer is also insured by the fact that corrugation gives more intimate contact between members of the sandwich.

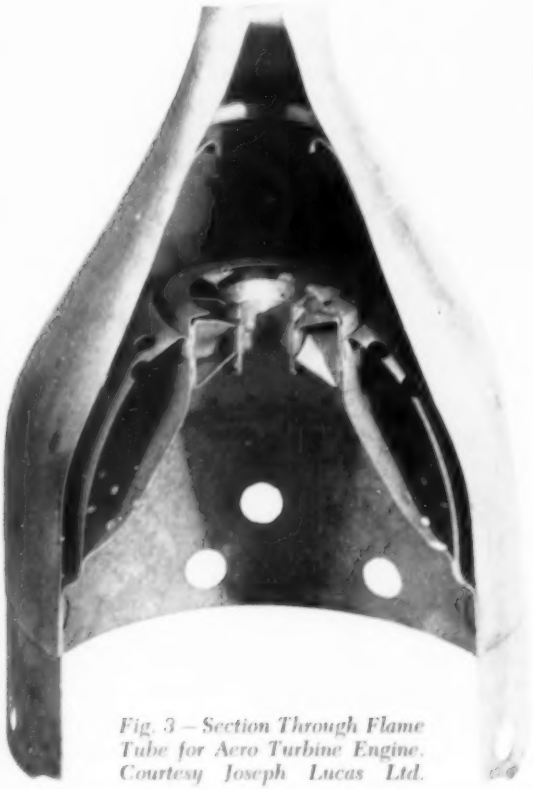


Fig. 3 – Section Through Flame Tube for Aero Turbine Engine. Courtesy Joseph Lucas Ltd.

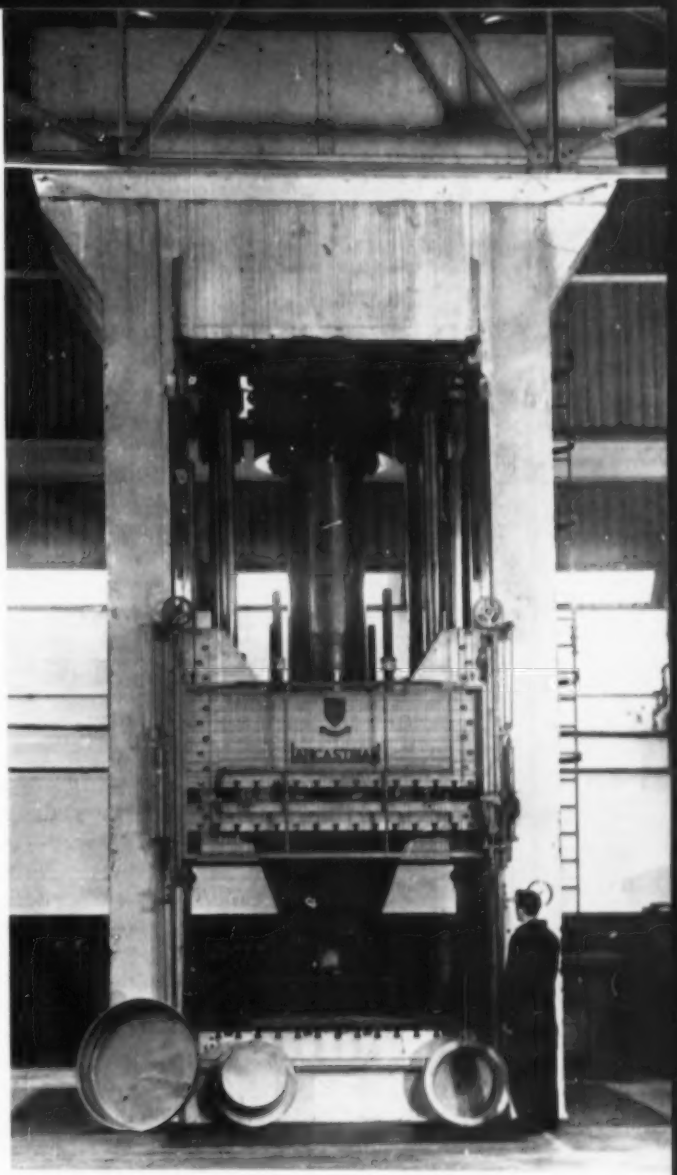


Fig. 4 – 1000-Ton Press for Stiff Nickel Alloys and Stainless Steel Sheet

Geneva Atomic Conference*

The Russian Contributions – The star attraction at the technical exhibits at the conference was the research reactor built at our Oak Ridge Laboratory and flown to Geneva. For most of the scientists and engineers come to deliver papers, it was their first view of an actual atomic reactor. The Soviet also had a large technical exhibit which was chiefly remarkable, from my point of view, for the fact that it *was* there at all. They demonstrated a scale model of their 5000-kw. reactor and a good motion picture of the reactor itself. They also indicated that larger power reactors of a different design were planned. We, of course, have had units substantially larger than the Soviet plant operating for a considerable time, and far larger ones are building.

Soviet contributions showed careful preparation and a considerable amount of detail. But it early became apparent that they were not prepared to engage in the same frank discussions as other delegations.

The Russian delegation, of whom 79 were technicians, were generally competent and, in some instances, exceptional men. As one of our people said, "They were good enough to be a first team." On the basis of their role at Geneva, they appeared stronger in basic research than in its practical applications.

The fact that we appear to be ahead in the peaceful applications of atomic energy – perhaps by a scant few years – certainly offers no justification for complacency. To the contrary, the situation must be regarded as a serious challenge. We did not show anything at Geneva which they cannot have in a few years, given the talent and zeal we believe they possess.

Too many of us have been thinking of the Russians, either by education or temperament, as not quite equal to us in technology. Despite the many things wrong with their political system, let us not assume that they cannot compete with us in mastering atomic energy. The early date at which they produced nuclear weapons should be a constant reminder of the fallacy and danger of such an attitude.

While other nations are engaged in extensive undertakings directed toward production of electric power, our program is substantially ahead in extent and in the versatility of its approach. Even today, the kilowatts we are producing in our reactors would be economic in some parts of the world.

Soviet Russia has no private industry interested in developing the peacetime uses of atomic energy and no spirit of competitive free enterprise. In Russia the whole show is a government monopoly. It will be interesting to see how this will affect the search for a more economic and efficient power system than the one they exhibited in their model and movie at Geneva.

The Chief Results – What were the chief results of the Conference? First, the free world – perhaps even the Soviet – has a new understanding of the sincerity of our desire "to strip the atom of its military casing and to adapt it to the arts of peace", to use President Eisenhower's words. Any suspicion of our motives, imported to the Conference, could not have survived the two weeks of Geneva, and many delegates volunteered that statement to me in similar words.

Second, communication was re-established between men of science. As a result, much cross-fertilization of ideas will occur and that, inevitably, will stimulate new inventions.

Third, there can no longer be any talk of nations which are "have not" nations from the point of view of possessing information for the peaceful applications of atomic energy. Development of atomic power is a very complex and expensive undertaking. The notion that all they have to do is place an order for a reactor out of a catalog and immediately be in business should have been dispelled at Geneva.

Fourth, we gained much information of value to ourselves from the Conference. One by-product was a rebirth of humility. We learned not to underrate the competence of others.

Fifth, all of us were impressed by the disturbing fact that Russia appears to be training scientists and engineers at a faster rate than we are. Furthermore our own colleges and universities are turning out only about half the number of engineers we require today. Unless corrected, this situation, a generation hence, will become a national calamity.

Sixth, and finally, in this listing of the results of the world's first Conference on the Peaceful Uses of Atomic Energy, I come to the brightest, most appealing of all its accomplishments. Wider horizons of grander view were opened. To many, it must have seemed that, overnight, the atom had been transformed from a thing of fear and terror to a promise of great blessing.

*Excerpts from speech by Lewis L. Strauss, chairman, U.S. Atomic Energy Commission, before the Atomic Industrial Forum, Sept. 28, 1955.

Atoms for Peace

Metallurgical Topics Discussed at Geneva

*By JOHN P. HOWE**

Demand for power is increasing so rapidly in Europe that uranium can already compete with coal as an economical fuel. Various power reactors now under construction or design were described at Geneva. Our reporter outlines some major unsolved problems relating to metallic materials of construction. (T 25)

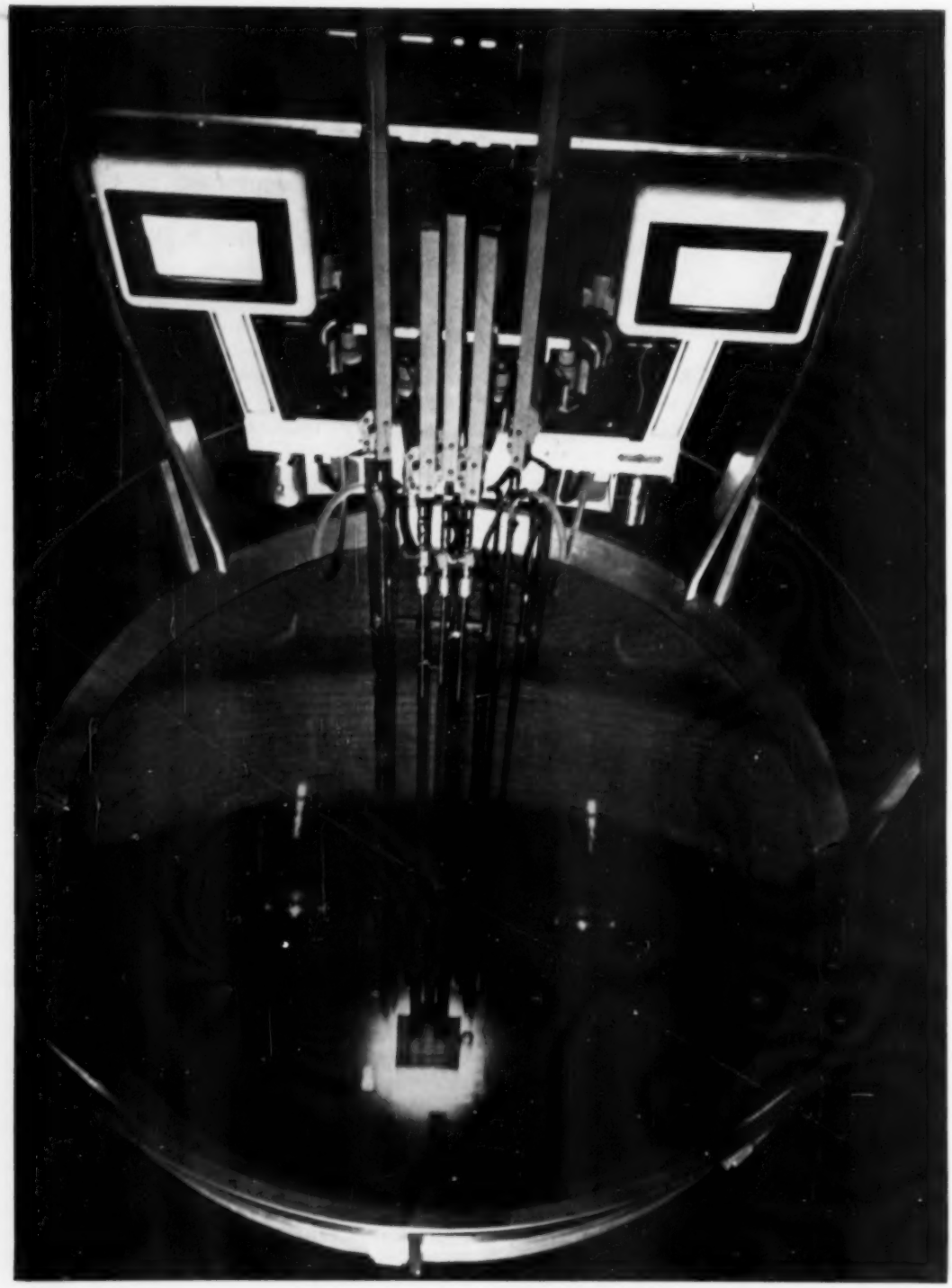
A NUMBER of metallurgists who are already beginning to age in the service of atomic energy, and with whom this writer is happy to identify himself, has been meeting together with reasonable frequency since about 1942. Our circle has changed and widened considerably, and on occasion we have discussed a few problems in public. It was, however, a very large step from the situation wherein we were talking largely to ourselves, to the Geneva Conference, at which we began to discuss metallurgical problems with our counterparts in other nations. Despite rather complete exchange of information within the A.E.C. about the building and operating of nuclear reactors, the Geneva Conference produced the first reasonably comprehensive review. Fortunately, the papers presented there mark only the beginning; as publication of metallurgical information proceeds, we will begin the process of review, criticism, confirmation, and systematization which builds the knowledge upon which our science and technology are truly based.

The large release at Geneva has led some people to conclude that a drastic change in declassification policy was arranged specifically for the Conference. Actually, the rules for declassification of information concerning nuclear reactors have been under constant review and revision since World War II. The present statement of the rules was formulated about two years ago and was based on an analysis of the needs of our nation and upon an appraisal of the development of atomic power throughout the world (together with, of course, American interests in military aspects). It is true, however, that once the plan for the Geneva Conference was announced, much information was hoarded and organized specifically for the conference. It placed a forced draft upon the organization and presentation of material.

Even nuclear physicists concede that the future of atomic power depends on the work of the metallurgist and materials engineer. Consequently, the information on materials and metallurgy presented at the Conference should tell the state of the art and the problems ahead. By and large, the papers measured up to this responsibility very well. It must be admitted, however, that the sessions on metallurgy attracted nothing like the number of people as did those on reactors and nuclear physics. Thus, it is not unlikely that – at least in the free world – the problems of materials will fall upon the shoulders of a relatively few individuals. We metallurgists should do something about this situation.

The fact that atomic energy has become a truly international affair was clear to any observer, what with "official delegations", messages from heads of state, and addresses by diplomatic chiefs, and a company of reporters for newspapers far and wide. At the very begin-

*Section Chief of Reactor Materials for Atomics International, a division of North American Aviation, Inc., Downey, Calif.



Self-Photograph of Swimming-Pool Type of Reactor Given to Switzerland by the United States. The eery blue glow is generated by neutrons speeding through the water which fills the tank

ning the needs for energy throughout the whole world were reviewed. It is easy to agree that with increased use of energy, the standard of living increases; also, that in the civilized areas, the use of electrical power doubles about every ten years. It is also easy to understand that the amount of uranium and thorium in the world offers a very large block of energy to be used in lightening man's burden. Furthermore, it is apparent that many areas of the world have a large amount of work to do, if they wish to have the things which can be provided by technology. However, the writer was left with the hope that the economist will find more interesting and appetizing ways to portray these ideas. Unquestionably, similar remarks may be made by economists about metallurgists. The writer was also struck by the fact that no question was raised throughout the whole Conference as to the correctness of the western definition of "progress"; a large number of eastern nations were well represented but the promise of technology was denied by no one.

After establishing the need for atomic energy beyond any doubt, the Conference sought to look into the nature of a nuclear energy enterprise by reviewing the experience with two power plants, one in Russia and the other in the United States. This study continued with an examination of money that may be required to support the future growth of power production from the nucleus, the prospects for balancing the budget through the sale of power and other materials, and finally the legal, administrative, and human safety aspects of the whole problem.

Extra-Curricular

Informal meetings with professional brethren provide a great deal more pleasure than, and perhaps as much value as, formal sessions themselves. In this regard the Geneva Conference was like the rest. At a very pleasant Saturday night gathering with H. M. Finniston, head of the metallurgy division of the British Atomic Energy Establishment, several of us heard an informal review by Meyerson of some volumes published by the U.S.S.R. just after its Moscow Conference last July. Some notions as to how the Russians are going about their work also came from this "bull session". There are a number of institutes for metallurgical studies in Moscow; apparently they are well supplied with help and with equipment. One gathers that a large number of metallurgists are being trained and that there is no shortage of talent in the

Autographs of Guests at a Small Dinner in Geneva Tendered by American Metallurgists

field. Apparently, aptitude tests determine qualified students very early in their career and suitable training, adequate equipment, and reasonable incentives are offered.

Some of the difficulties over language which occurred in the formal sessions were cleared up at such gatherings usually to the merriment of all concerned. Cyril Smith learned that during a discussion of dislocations and radiation effects, the phrase "Frank Read source" (of dislocations) came out in a Russian version as a "concrete source"; in another the word "openhearth" was translated into Russian as "open house".

The American metallurgists were able to reciprocate in part for many pleasant affairs and new contacts by entertaining a group of metallurgists and metal scientists from the various delegations. Most of us collected autographs; a complete set is reprinted here to indicate the wide representation and to signify the very pleasant association which was possible. This writer still marvels at the situation men-

One of the Twin Power Reactors Under Construction at Calder Hall, England (Photo copyright U.K. Atomic Energy Authority)

tioned in the introduction in which only a little while ago his chief metallurgical acquaintances were within the U.S. Atomic Energy Commission; now suddenly he feels he knows metallurgical engineers and scientists in a large number of other nations.

Power Reactors

U.S.S.R. – The most exciting point in the technical discussion, if not in the whole conference, was the discussion by Blochinzev, head reactor man in the U.S.S.R., on their 5000-kw. nuclear reactor power station, and by Zinn, America's top reactor man, on the power plant at Arco, Idaho. The Russians are first in putting significant amounts of electrical power on the line for over a year. Zinn explained clearly, however, and without apologizing, that our problem is not simply to produce power, but rather to produce power at a suitable price which makes it of some use in the economy.

Blochinzev's talk, together with a model and movie, gave a fairly detailed description of the Russian power plant, but problems connected with materials were not mentioned. The primary coolant is water under pressure, conducted through the reactor in stainless steel tubes around which the uranium, enriched to 5% U^{235}, is placed and in turn enclosed in a stainless steel tube. Fuel elements are appropriately spaced in a graphite moderator in bundles of five. A central element surrounded by four provides a lead-in and return of water from the supply and exit headers which lie over the reactor. A number of careful questions failed to pry out the details of how the Russian fuel element is held together – the nature of the uranium or uranium alloy or how it is bonded for good heat transfer to the coolant tube. Apparently some 15% of the U^{235} in the fuel is "burned".

Pressurized water is on the order of 465° F.; low-pressure steam is generated at a somewhat lower temperature, and clearly the fuel and the graphite operate hotter. A fairly low ratio of 0.32 for conversion of U^{235} to plutonium is due to the small size of the demonstration reactor and degree of enrichment of the fuel. In addition, it indicates either a considerable amount of stainless steel in the tube walls or possibly the presence of some alloying elements with the uranium.

United Kingdom – The program in the United Kingdom is directed in a very real way by considerations related to materials. Since the British could appropriate no enriched uranium for this use, and the cost of heavy water is high, a graphite-moderated reactor is about the only one possible. To achieve reasonable steam power temperatures, the reactor is gas cooled. Their fuel elements will be natural uranium jacketed with aluminum-magnesium alloys and cooled with CO_2 at about 400 to 500° F. Fuel element surface temperatures may not go beyond about 700 to 750° F. Thus, steam at rather low pressure will be generated. In the second series of reactors, as planned, the British are looking forward to liquid metal cooling, the use of slightly enriched uranium in graphite-moderated reactors, and highly enriched uranium and plutonium in fast breeder reactors.

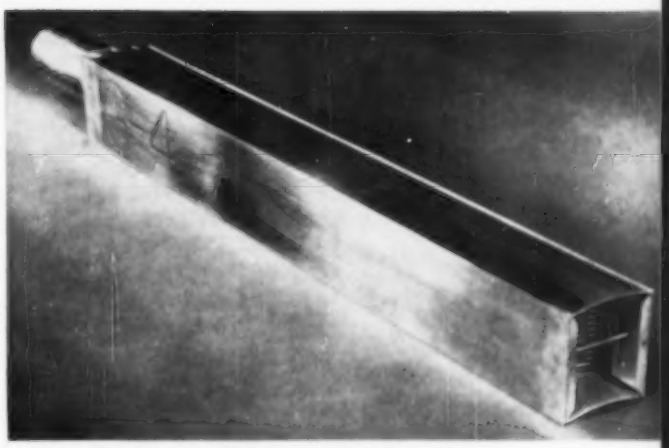
We have been exchanging information on reactor technology with the British since World

War II, and many of us have been impressed with their thorough attack on a limited number of carefully chosen problems. Apparently several countries are very much impressed with the British approach to their first round of power plants, for they can obtain natural uranium and graphite and feel they can master the fairly simple technology of the CO_2-cooled reactor. They do need information badly about the cladding of fuel elements.

France – The reactor program in France is somewhat parallel to the early round of power reactors in Great Britain. At the Saclay Laboratory the French Atomic Energy Commission is operating a heavy-water moderated reactor wherein nitrogen at several atmospheres pressure is circulated over natural uranium bars clad in magnesium. This experience is being extrapolated to plants for producing plutonium and power to be located in the south of France. Both types will be gas cooled; plutonium producers will be heavy-water moderated; power reactors will be graphite moderated. The French scientists and technologists now have enough experience to have met about all of the basic problems, and have appropriate investigations in progress. Among these are the development of long-life, stable fuel elements, information on limiting temperatures and heat transfer, stability of moderator materials, and all the nuclear constants and methods of calculating the behavior of reactors.

Norwegian countries have under way excellent nuclear energy programs centered at the moment around reactors moderated with heavy water and fueled with natural uranium. The Norwegians and Dutch have had a research reactor of this sort in operation since mid-1951 and are now cooperating on a power reactor program.

America – Zinn's paper, mentioned above, told about a reactor moderated by boiling water, from which steam is led directly to a turbine. Its stability is good enough for practicable application. Although its power density is low, it is not discouragingly so. The large pressure vessel required for a practicable power plant is still feasible, even though it must withstand pressures of the order of 2000 psi. at temperatures approaching 550° F. The fuel element is not entirely certain, because slightly enriched uranium alloys are not satisfactory in high-temperature water or steam, but it is hoped that fuel elements incorporating uranium oxide will work. A suitably inexpensive and stable fuel element remains a central question.



Fuel Unit in the "Swimming Pool Reactor" Erected in Geneva by the United States and Given to the Government of Switzerland

The pressurized water reactor which is being constructed at Shippingport, Pa., was described in contributions from Westinghouse Atomic Power Division. The use of high-pressure water to moderate and cool the reactor has already been demonstrated. However, as above, the construction of economical fuel elements remains a prime problem. This reactor will use uranium oxide incorporated in zirconium tubes together with other fuel elements containing enriched uranium embedded in zirconium.

The design and operation of an experimental breeder reactor at Arco under the Argonne National Laboratory, and the design of a larger scale demonstration of the reactor principle for production of power and fissile materials, were described. Little doubt remains that a reactor of this type will breed – that is, generate more plutonium than it burns up, but the precise gain in a large-scale system is not known accurately. Liquid metal cooling of a fast reactor has been demonstrated, but the cheap construction of long-lived fuel elements which can transfer power to the liquid coolant at the very high rate required for economical power production has not been demonstrated.

The sodium-graphite reactor program at Atomics International, a division of North American Aviation, Inc., was also described in considerable detail as to design of the reactor experiment to test the concept, the extrapolated design of a full-scale power plant using uranium-base and thorium-base fuels, and the inherent technological problems. Many of the latter relate to materials, and they may be summarized as

Magnified Cross Section of Geneva Fuel Element. Cross pieces are sandwiches, 2 S aluminum clad. Center fuel is pressed mixture of aluminum and uranium dioxide powder

follows: long-lived fuel elements (incidentally, there are excellent prospects in this problem), and the prevention of oxygen pick-up by zirconium (in which the graphite moderator is canned in order to protect it from sodium coolant). This oxygen is adsorbed on the graphite inside the zirconium cans, and in the sodium which must contain no more than the limiting 30 parts per million. The real potential of this reactor will be the achievement of high power output and efficiency through the use of high-temperature materials useful above 1000° F. and will depend upon the development of fuel elements whose temperature will be permitted to exceed 1500° F.

Perhaps the development problems in all the above reactors which utilize solid fuels are summarized by W. B. Lewis, vice-president of the Atomic Energy Co. of Canada, to the effect that he had found no one at the Conference who had a good fuel element!

Fluid Fuel—Troubles with fuel elements bring up the subject of reactors with fluid fuel. Homogeneous reactors were discussed by workers at Oak Ridge National Laboratory. In them the problem of fuel elements is exchanged for problems in handling of high radioactive aqueous solutions of uranium salts at high temperature and pressure.

Liquid metal fuels, discussed in a paper from the Brookhaven National Laboratory, may also avoid some of the above-mentioned difficulties without introducing others equally baffling. Bismuth solutions may be contained in ferritic high-temperature steels and in graphite.

Other fluid fuel reactors were discussed by deBruyn and Went of the Netherlands. One concept is based on fluidized solids, such as the suspension of uranium oxide in water, or on the suspension of uranium oxide in a gas. Chemical and physical stabilities of these dispersions are perhaps the greatest unknowns in such suggested reactor systems.

Metallurgy

Eighteen half-day sessions were devoted to the general field of chemistry, metallurgy and technology wherein numerous papers, most of them summaries of large bodies of work, were read. If the following collection of topics appears to transcend the subject of metallurgy, the blame can be placed partially on the requirements of atomic energy.

Remote Methods—Three papers, one each from the United Kingdom, United States, and Russia, described procedures for handling thousands of curies of fission products. Metallurgists may wish to take note of methods for cutting, polishing, and etching specimens of uranium, and of photographing—all by remote control. Some of the Russian micrographs were particularly well made.

Radiation damage was treated in excellent style. This is a new field which is enriching metallurgy and the study of materials greatly. Billington of the Oak Ridge National Laboratory reviewed extensive work on reactor materials, and showed how the defects in crystal lattices produced by fast-moving particles raise the critical shear stress of metals, disorder copper-gold alloys, and raise the transition temperature for ductile-to-brittle fracture in molybdenum. He also discussed the dimensional instability of uranium single crystals and textured uranium bodies under irradiation and under repeated heating and cooling, as well as the rather large change in mechanical (but not electrical or thermal) properties which occurs when uranium is irradiated. Aluminum-uranium alloys containing small amounts of uranium, such as used in fuel elements for research reactors, can withstand

(Continued on p. 154)

Göran Fredrik Göransson, Successful Operator of Bessemer's Process at Edsken, Sweden, in 1858, and Founder of the Sandvik Steel Works Co., Ltd.

The First Successful Bessemer Steel

*By KARL FREDRIK GORANSSON**

Bessemer's equipment, set up in Sweden and supervised by a representative of the inventor, could not make marketable steel until – at Göransson's direction – the tuyeres were enlarged so that much more air at lower pressure could be blown through the molten pig iron. (D 3, ST)

Göran Fredrik Göransson, a merchant in Gavle, a port on the Baltic some 125 miles north of Stockholm, met Henry Bessemer on a journey in England in 1857, the year after Bessemer had disclosed his new method for steelmaking. Göransson had some interests in the iron industry of his home district and he recognized the great importance the new process could have if it could be exploited practically on a large scale. He therefore acquired from Bessemer some of the patent rights for Sweden and Norway and, returned home, started experimenting at Edsken, not far from the place where the Sandvik Steel Works now is situated.

As agreed upon at their meeting, Bessemer sent a converter to Göransson as well as a man to give him directions how to operate the new installation. However, it soon became evident that the converter was difficult to handle and that the expected results did not appear. A new converter was therefore built, of a type Bessemer had previously arrived at by experiments, but with certain alterations with his approval. Görans-

*Chairman of the Board of Directors (and former President) of Sandvik Steel Works Co., Sandviken, Sweden, and grandson of the founder.

son was thus in close contact with Bessemer during the whole of these experiments and received many a piece of advice from him. Still the resultant product was not at all uniform and as a rule full of slag. Finally Göransson realized that the British assistant could not help him any longer and the assistant left Edsken.

It seemed enormously difficult to get a malleable product by the method that had been so full of promise. Göransson had no training in metallurgy and he carried out the experiments with the help of engineers and foremen. It was said afterwards that if he had had real knowledge in this field he would have soon realized the hopelessness of proceeding. He and his assistants went on, however, experimenting during the whole first half of 1858, and their work was characterized by a certain scientific approach – namely, all possible combinations and circumstances liable to influence the course of the process were controlled most conscientiously and critically.

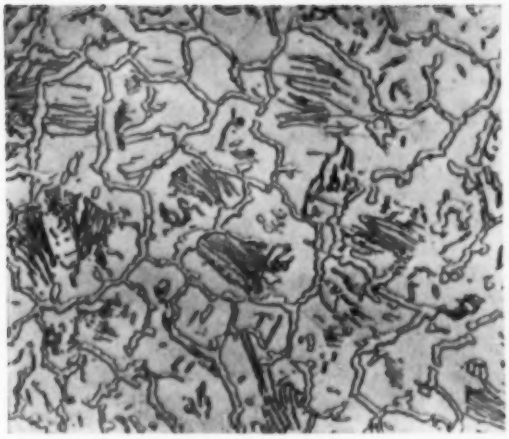
Göransson received monetary aid from Jernkontoret (the Swedish Ironmasters' Assoc.) but was threatened at last by economic ruin and a total fiasco. In a letter written much later to one of his friends he describes this critical stage and his eventual success as follows:

"We tried every possible means of augmenting the pressure of the blast by reducing the diameter of the tuyeres and using smaller charges, as we had reached the limit of the pressure which could be produced by the blast engine, but all with less and less success. On the point of giving up the experiments, I resolved, in spite of all advisers, to *diminish* the pressure and, instead, use a larger quantity of air. For this purpose we put all 12 tuyeres in one line at the bottom of the converter, and enlarged their diameter to seven-eighths of an inch. The result was astonishing! The temperature of the fluid steel was raised very much, the slag came up on the top beautifully, the ingots turned out even in temper (carbon), free from slag, and extremely malleable, more so than any iron made by the old process. The first charge with the converter, so arranged, was made on the 18th of July, 1858, and from that date the bessemer method can be regarded as successful."

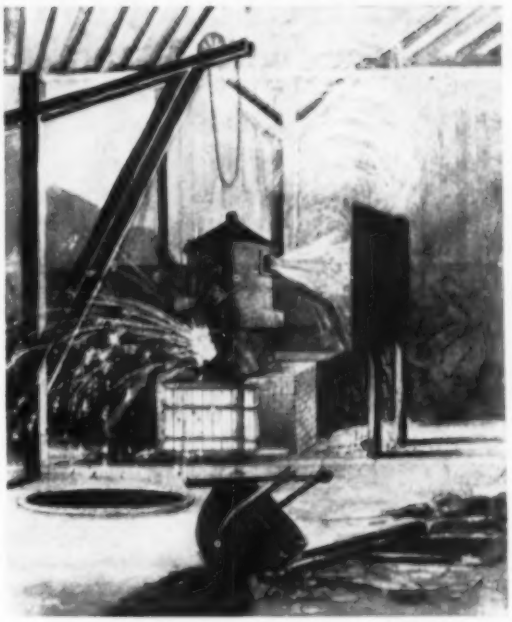
In the meantime, Henry Bessemer was also busy working at the development of his converter and method of steelmaking, but he also met with great difficulties. It is quite obvious that Göransson's achievement at that moment became a decisive factor. This appears also from the continuation of the above letter that Göransson had written in November 1879, on the recommendation of one of his friends, 21 years after the summer day on which his assiduous work was crowned with success. He continues as follows:

"I sent 15 tons of ingots to a firm in Sheffield and 15 tons to Messrs. Henry Bessemer & Co.'s works at the same place, and went over to England in September (1858) to have them tested. I found then that Mr. Bessemer had not succeeded in his efforts at steelmaking, but had to granulate the steel he got from the converter in water and afterwards remelt it in crucibles. As such a process could not give any profit, the friends who assisted him were losing all hope of success, but they all came down to Sheffield to see my ingots before they finally gave up this business. The other Sheffield firm, thinking it their interest not to promote the bessemer method, got the whole lot 'burnt' at the washwelding, but the 15 tons hammered and tilted at Messrs. Henry Bessemer & Co.'s works turned out to full satisfaction after having been made into knives, scissors, razors, other tools and plates."

Test Ingot From One of the Very First Bessemer Blows in Sweden in 1858. Full size. Recarburized steel, solidified during excessive evolution of gas. Analysis 1.05% C, 0.01% Si, 0.02% Mn, 0.021% P, 0.004% S



Microstructure of Test Ingot Near One of the Blowholes. Etched in 4% picral, 750 ×. Well-developed cementite network surrounding ferrite grains, some of which contain isolated cementite crystals and some containing lamellar pearlite. Bengt Soderlund, metallographer



Blowing a Bessemer Converter at Edsken, Sweden. (From a contemporary water color)

As far as is known, this was the first successful bessemer steel, commercially marketable, made anywhere in the world.

From the above it would be assumed that the soft steel, the low-carbon product of the converter, had been recarburized to "general purposes temper" – 0.90 to 0.95% carbon – and indeed this was true. One of the first bessemer ingots made in Edsken is now preserved at Sandviken. Descendants of one of Göransson's assistants at the experiments at Edsken kept the small test ingot and gave it to the Sandvik Steel Works in 1947. The structure of the steel was then examined, and the photograph alongside and micrograph above were some years later awarded an "honorable mention" at the National Metal Congress of the American Society for Metals. The analysis of the steel turned out to be as follows: 1.05% C, 0.01% Si, 0.02% Mn, 0.21% P and 0.004% S.

After the success at Edsken the bessemer pneumatic method of steelmaking could be looked upon as having been carried out under practical working conditions, and rapid further developments took place in many countries. How the steel industry expanded, thanks to the new possibilities opened up by the bessemer converters, is best illustrated by the development which Göransson personally headed during the next few decades. After 1858 he produced much steel at the original plant at Edsken, but he soon found the possibilities there too restricted and in order to exploit the business on a larger scale he founded in 1862 the works that were later on called Sandvikens Jernverks Aktiebolag (Sandvik Steel Works Co. Ltd.). The number of persons employed rose during the period from 1870 to 1900 from 300 to 2000. Today, more than 6000 people are employed at Sandviken and the company is represented by 125 subsidiaries, affiliates and agents in 74 countries.

The new plant had from the beginning a considerable array of forging and other mill equipment. The large steam hammer, for instance, became almost legendary with its 15 tons working weight, being at that time the second biggest in Europe. It was built by Messrs. Kirkstall Forge Co., Leeds, England and was delivered by Messrs. Hinde & Gladstone of London. It now stands in the park in front of the head office as the symbol of the works' early days. The early production of the Sandvik Steel Works was, of course, dictated by the great demand for material for shipbuilding, railroads and rolling stock, and the company's principal output was rolled tires for the railway car wheels, propeller shafts, and other heavy forged or rolled articles. Bessemer steel from Sandviken found its way out to the world markets and soon became famous for its high and even quality.

Metallurgical Research in India

*By R. F. BUNSHAH**

Despite a small amount of money available for research – estimated at about $250,000 annually for metallurgical topics – some notable work is being done in four governmental, four university and one industrial laboratory, from which several new manufacturing processes have been derived. (A 9)

Though the arts of ironmaking were well known and practiced in ancient India, modern scientific and industrial research is now in its early stages. The new democracy of India joined the community of free nations on August 15, 1947. Since then, the importance of scientific research to the nation's growth and prosperity in this technological age has received due recognition. Scientific research has made great strides during the past eight years.

While the events of World War I emphasized India's shortcomings in the industrial age, it was 1935 before the Industrial Intelligence and Research Bureau was set up as a foundation on which a research organization suitable to the needs of the country could be built, but its activities were circumscribed by a very small budget. World War II, with its attendent problems, re-emphasized the desirability of making India industrially self-sufficient and an efficient base for war supplies, and brought the slender scientific potential of the country into sharp focus. A Board of Scientific and Industrial Research was established in 1940 and a few urgent problems pertaining to the war effort were investigated in the director's laboratory. In 1942, the then government of India established an "Industrial Research Fund" and the Council of Scientific and Industrial Research was constituted as an autonomous body to administer it, and to organize, set up and develop a complex program. The council consists of representatives of science, industry, labor and education. Its most important aims are:

1. Organization, construction and maintenance of national research laboratories and specialized research institutes, to carry out both basic and industrial research, the latter up to the pilot plant stage.
2. Stimulation of pure and applied research in the 27 universities of India by grants-in-aid and by scholarships and fellowships.
3. Coordination of all research activities.
4. Increase the supply of technical personnel by scholarships for study in India and abroad.
5. Stimulation and encouragement of research by private industry.
6. Function as a "national trust" for patents.
7. The creation of a board of standards and specifications.
8. Encouragement of scientific and technical societies.
9. Documentation services for scientific literature in cooperation with the United Nations Educational, Scientific and Cultural Organization.

All these aims and functions are being pursued to the extent of available funds, resources and personnel. Another notable step has been the creation of the National Research Development Corp. of India in 1953 along the lines of a similar organization in the United Kingdom.

*Dr. Bunshah is a graduate of Benares Hindu University, and has been awarded the Hadfield Medal by the Mining, Metallurgical and Geological Institute of India. After working in both Mukand and Tata Steel Works, and after graduate studies at Carnegie Institute of Technology, he emigrated to America and is now Associate Engineering Scientist at New York University.

As is well known, India is very largely an agricultural nation. Its industrial output is much smaller, both relatively and in quantity, than in the Western nations. For example, the annual steel production in India is 1,500,000 tons compared to 125,000,000 tons in the United States, yet the population is more than twice as large. Only 1.8% of the labor force in India is employed in factories out of which 6.5% of the national income is derived. Thus, of necessity, most of the research effort in India is financed by the government, either in national laboratories or as sponsored research in other institutions.

Financing

Activities of the Council of Scientific and Industrial Research are supported by annual grants. Roughly ½% of the federal budget is spent on research as compared to 3% of the United States federal budget — a low figure since the greatest emphasis in India's first Five-Year Plan, 1951 to 1956, has been on the development of hydro-electric power, irrigation and agriculture. During the later stages of this plan and during the second Five-Year Plan, considerably greater emphasis and financing will be devoted to expansion of the industrial potential, particularly iron and steel manufacture, and consequently to scientific and industrial research.

Approximate figures for fiscal 1954 are: Federal budget totals Rs 4,388,000,000 or $880,000,000 at official exchange rate. (In terms of actual services obtained, the writer's estimate is that the rupee buys nearly twice as much as the official rate implies.) In 1954 about Rs 20,000,000 or $4,000,000 was appropriated for all activities listed above, except construction of laboratory buildings and equipment.

Another significant comparison is the industrial contribution to research. In a highly mechanized society like the United States, industrial research expenditures by industry at least equal those of the government, but in agricultural India, industrial contributions are relatively insignificant. According to Sir Alfred Edgerton, who has twice reviewed the matter at the request of the Indian Government, most industrial concerns are too small to maintain laboratories and did not realize the advantages of forming cooperative research associations.

Consequently it results that the Rs 20,000,000 allotted by the Indian Government to research is augmented by Rs 2,000,000 at the most from industry, making a total equivalent to about $4,500,000 in 1954, of which no more than $250,000 was allotted to metallurgy. Contrast this with the $2 billion allotted to research by the American Government, plus an equal sum expended by industry, of which total a sum approaching $200,000,000 is spent on metallurgy.

Survey of Indian Governmental Research

Most of the metallurgical research in India is in four government laboratories, four university laboratories and a few owned by industry.

National Metallurgical Laboratory was opened in November 1950 at Jamshedpur in the state of Bihar at the center of the Indian iron and steel industry. Its activities fall into six divisions — general metallurgy, physical metallurgy, chemistry, ore dressing, refractories, and mechanical metallurgy. The total staff in 1954 amounted to 252 persons.

Work can also be divided into three categories — applied research, basic research and technical aid to industry. Applied research includes the production of nodular cast iron and study of nodularization, foundry sands, aluminized steel sheets, direct thermal reduction of aluminum-silicon alloys and reduction of titanium tetrachloride by electrolysis or the decomposition of various titanium salts under vacuum, zirconium metal, germanium, preparation of all kinds of refractory alloys including super-refractories, corrosion, fatigue and wear resistance. Among the processes developed to the stage of commercial exploitation are the production of low-carbon ferrochromium, manufacture of high-purity manganese dioxide and electrolytic manganese, beneficiation of low-grade manganese, chromium and tungsten ores, and the production of sillimanite refractories from indigenous material.

Basic research includes work on abnormality in carburized aluminum-bearing and alloy steels, on metal powders, on the transformation of austenite (particularly the bainite reaction), on austenite grain size control, X-ray studies on fatigue cracks, and determinations of the dynamic elastic constant and the effect of temperature thereon.

Technical aid to the industry includes such services as replies to technical inquiries which do not involve experimentation, routine testing, and minor investigations. This aid is rendered to a variety of industries, research institutes, other governmental departments, and to individuals.

National Physical Laboratory is situated at Delhi and was opened in January 1950. One of its important functions is to establish standards of measurement. In the applied mechanics division all kinds of mechanical testing can be done.

Metallurgical research includes such topics as photo-elasticity, vibration analysis, stress analysis, elasticity, finishing and plating of metals. A magnetic fluid and a fluorescent fluid for crack detection have also been developed. Research in basic metallurgy includes electron diffraction studies on thin metallic films, passivity of stainless steels, and determination of thermionic constants of metals and alloys.

National Chemical Laboratory was opened at Poona in March 1949. Some fundamental research is done on metallurgy of surfaces using electron diffraction, on the structure and nature of electroplates, on metal films deposited from vapor, and on phase transformations. A new body-centered cubic phase of nickel has been reported in the temperature range of 300 to 400° C., corresponding to the specific heat anomaly in that region.

The Atomic Energy Commission Laboratories are currently situated in temporary quarters in Bombay. The metallurgical activity includes such topics as the beneficiation of uranium-bearing ores in India. A particular achievement is the separation of hafnium from zirconium by vapor phase dechlorination. This sponsored work was done at the Indian Institute of Science, and presented at the recent International Conference on Peaceful Uses of Atomic Energy at Geneva, where it received high acclaim. The world authority on cosmic rays, H. J. Bhabha, is also remembered as the presiding officer (or President) of the international conference on Peaceful Uses of Atomic Energy at Geneva.

University Research

Indian Institute of Science, at Bangalore, has a metallurgy department which grants diplomas after completion of required course and research work. Research topics being investigated here include aluminum coating of steel, aluminum alloys for electrical conductors, production of aluminum by electrolysis of molten anhydrous aluminum chloride, electrodeposition of cobalt from fluoborate baths, internal stresses in electrodeposited cobalt, electrolytic preparation of titanium, chromium plating of cast iron, elastic modulus at elevated temperatures, elastic properties of single crystals, metallurgy of beryllium, and the improvement of strain gages.

Bengal Engineering College, at Howrah, is primarily concerned in its metallurgy department with undergraduate studies, but a very considerable amount of fundamental research is undertaken by research scholars and faculty members. Topics include X-ray investigation of binary alloys of metals with dissimilar crystal structure, valence and ionic radii, damping capacity of steel using thermal evolution methods, new alloys conserving strategic elements like Cb, Ni, and Mo, diffusion studies in alpha brass, nature of hardness, rates of film formation, a new aging phenomenon in iron and steel based on anodic surcharging, low-temperature tempering of quenched steels, and gases in steel.

Benares Hindu University was the first institution to give degree courses in metallurgy in India. While the departmental faculty is primarily concerned with teaching, some research is being done on alumino-thermic reactions and on high-purity titanium.

Indian Institute of Technology at Kharagpur is the first of a chain of institutions to be set up on the pattern of Massachusetts Institute of Technology. The metallurgy department is now being organized. Some studies on the hardenability of steels have been undertaken.

Industrial Laboratories

Most of the laboratories associated with industry are mainly for process control, but the research and development laboratory of the Tata Iron and Steel Co. does a considerable amount of fundamental work, mainly concerned with iron and steel manufacture. New processes and techniques in steelmaking, viscosity of high-alumina blast furnace slag, and electrolytic manganese as an alloying element in steel may be cited.

Publications and Patents

Information derived from the work listed above is published in such journals as the *Journal of Scientific and Industrial Research*, *Transactions* of the Indian Institute of Metals, and in foreign journals. Among the most important metallurgical patents which have been granted are those pertaining to cyanide-free brass plating bath, metallization of nonconductors, utilization of manganese ore, and electrolytic production of high-purity manganese.

Since the common scientific language is English, a rather unique publication is a monthly bulletin printed in Hindi, the *Vigyan Pragti*, whose purpose is to inform the people engaged in small-scale and cottage industry.

In conclusion, it may be said that this young democracy, India, has set about the task of national reconstruction on a firm scientific basis. With an abundance of resources and manpower, industrial progress should be rapid.

Australian Production of Ductile Chromium*

By H. L. WAIN†

Pure chromium metal, hitherto thought to be extremely brittle, has good bend ductility at normal temperatures if sufficiently low in nitrogen, especially in the extreme surface layers. The metal can be readily extruded and rolled, but final working should be below recrystallization temperature. (Cr)

CONTINUOUS and at times intensive work has been under way since 1946 at the Aeronautical Research Laboratories in Melbourne, Australia to devise new alloys and methods of manufacture of gas turbine rotor blades to replace the ones currently using much strategic metals such as nickel, cobalt and columbium.

Chromium was chosen as the basis for such an alloy after reviewing potentially suitable materials, using the theory of alloying and such other general concepts as were available at that time. This theoretical survey indicated that chromium should have high interatomic and intergranular cohesion, and high resistance to oxidation and low density as compared with the other possibilities, tungsten or molybdenum. This choice has subsequently been vindicated since it has been shown that chromium has the highest strength-density ratio of a considerable number of pure metals tested in creep at 1000° C.

The main difficulty with commercially pure chromium was (and still is) its brittleness. It has no significant ductility at room temperature. Consequently the first objective was to produce

*Excerpts from a paper entitled "Research on Chromium in Australia" read before a conference on ductile chromium and high-chromium alloys held at the ASM Convention in Philadelphia in October 1955. The complete paper will be published with the other contributions in a volume to appear in the spring of 1956.

†Aeronautical Research Laboratories (A.R.L.), Research and Development Branch, Department of Supply, Commonwealth of Australia. The author desires to acknowledge the assistance of many of his associates at A.R.L., as well as in the Defense Standards Laboratories, which have studied the problems as a joint project.

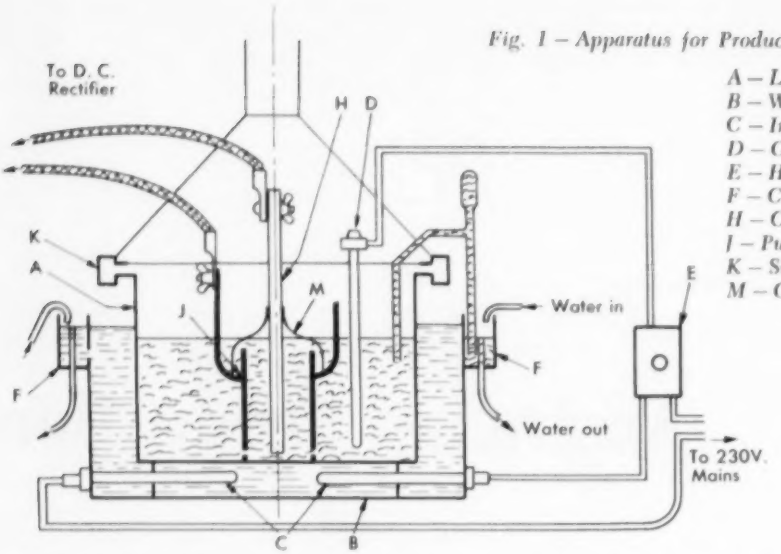


Fig. 1 – Apparatus for Producing Electrolytic Chromium

A – Lead-lined plating bath
B – Water jacket
C – Immersion heaters
D – Glass-sheathed thermostat
E – Hot-wire vacuum switch
F – Constant head devices
H – Copper cathode
J – Pure lead anode
K – Suction duct
M – Glass bell

metal which would be sufficiently tough to withstand normal handling, machining, fitting, and working loads up to temperatures where it becomes tough. What follows can only outline our successful work on chromium, although extensive studies have been made on several binary alloys. An indication of our success in getting strong (hard) alloys when hot may be gained from the statement that the much-used Nimonic 80 A has Brinell hardness of 125 at 900° C., a 99-1 Cr-Be alloy has Brinell 170, a 65-35 Cr-W alloy has Brinell 250 and an 85-15 Cr-Ti alloy 280.

Production of Pure Metal

When work was begun at A.R.L., no chromium had been produced with any room-temperature ductility apart from metal tested in compression at slow rates of deformation. The first problem to be solved was, therefore, to produce chromium in a ductile form at room temperature and to determine the factors producing embrittlement. It seemed proper to use electrodeposited chromium as starting material, since it is relatively simple to produce it with a very low metallic impurity, and oxygen and hydrogen can readily be reduced to low levels.

Our chromium is produced by the electrolysis of chromic acid, and the type of cell first used at A.R.L. is illustrated in Fig. 1. It consists of a lead-lined plating bath contained in a water jacket in which are two immersion heaters. Temperature is regulated by a glass-sheathed thermostat and a hot-wire vacuum switch. Water levels in bath and heating jacket are controlled by two constant head devices. The cathode consists of a copper tube "stopped off" with polyvinyl chloride tubing and the anode is a cylinder of pure lead. A glass bell covering both anode and cathode collects most of the chromic acid spray, and fumes are removed by a suction duct.

The electrolyte consists of 300 g. per l. commercial chromic acid (a local product), 4.0 g. per l. sulphate ion (chemically pure sulphuric acid) and domestic water. The chromic acid contained very few impurities on spectroscopic analysis: a strong trace of copper, faint traces of Si, Na, Fe, and Bi, a very faint trace of calcium, and no detectable amounts of other metals, P, As, and B.

The cells were run continuously at 85° C. (185° F.), and current density of 880 amp. per sq.ft. Bath composition was checked frequently and additions were made as required. Cathodes were changed twice weekly and the chromium was stripped by dissolving the copper cathode in nitric acid, after which it was washed and dried. Nodules which fell to the bottom of the bath are not recovered. Production from one cell is about 1 lb. per week.

The above practice differed in the following respects from that used for commercial plating:

1. Pure lead was used in contact with chromic acid instead of antimonial lead, since the latter was found to contaminate the deposit with 0.2% antimony.

2. The cell temperature was higher, which required polyvinyl chloride rather than commercial "stopping-off" waxes.

3. The high temperature and low current efficiency led to a considerable loss of chromic

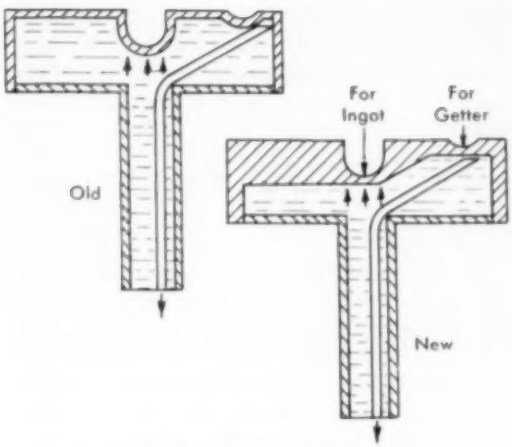


Fig. 2 – Modification to Hearth of Argon Arc Furnace to Prevent Burn-Through

acid by spraying – about 1 lb. of acid per pound of chromium produced.

The chromium deposited under the above conditions contained approximately 0.05% by weight (0.15 at.%) oxygen, 0.003% (0.009 at.%) nitrogen, and hydrogen as its major impurities. Spectroscopic analysis failed to reveal the presence of any metallic impurity in amounts greater than "faint trace".

Much work was done on the effect of plating variables. In summary it may be said that oxygen in the deposit can be lowered from 0.12 to 0.01 wt.% merely by raising the bath temperature from 160 to 190° F. This lowers current efficiency simultaneously from 6.5 to 5.0%. As regards bath compositions the most important factor is the CrO_3: SO_4 ratio; high values lead to high oxygen contents and low current efficiencies; about 60 is optimum. Time of continuous plating (up to 75 hr.) has no influence on oxygen content, nor does current density between 1100 and 880 amp. per sq.ft. Controlling the atmosphere above the plating bath, or limiting the dissolved gas in the bath, or using highly purified raw materials has not reduced the oxygen contained in the electrodeposited chromium.

Analysis by weight percent of metal currently made is 0.02% O_2, 0.0025 N_2 and 0.009 H_2 (all by vacuum fusion). Spectroscopic analysis gives faint traces of Cu (about 0.0025%), Ag (less than 0.0005%), Mg and B (both less than 0.005%), very faint traces of Si and Ca (both less than 0.001%) and no other elements detected. The oxygen content in this metal has been reduced to extremely low values by heating in pure hydrogen at 1000 to 1500° C. (1800 to 2700° F.), but this is not used in our production, since the 0.10 to 0.20% oxygen in the electrodeposit does not seem to be responsible for brittle behavior.

One somewhat troublesome feature of our process is that the high-purity lead anodes tend to passivate if the current is stopped even for a few minutes. Wire brushing is sometimes effective in rejuvenating passivated anodes, but in other cases they have to be discarded. The addition of small quantities of antimony or silver to the lead reduces this trouble, but unfortunately these metals deposit in the chromium. Small additions of tin to the anode material may be more effective.

Electroforming might be a useful way to manufacture a shape approaching that of a turbine blade. Deposition from organic and fused salt baths seems to offer the best prospects. Solutions of anhydrous chromic chloride and anhydrous chromic acetate in a variety of polar organic solvents have so far proved unsuccessful. Fused salts to be tested include chlorides and mixtures of CrO_3 and $Na_2B_4O_7$.

Melting and Casting

The apparatus and technique for melting chromium at A.R.L. in an argon arc furnace to produce small cylindrical ingots approximately 2 in. long by ¾ in. diameter and weighing 70 to 80 g. have already been described in *Journal* of the (British) Institute of Metals, Vol. 83, 1954, p. 126, and will only be mentioned briefly. (We have a larger furnace which makes 1-lb. ingots, 1.5 in. round and 4.5 in. long.) Melting is done on a water-cooled copper hearth under a gettered argon atmosphere at a pressure of 80 to 90 mm. Hg. A direct-current arc is struck between a negative tungsten electrode and the charge, which is first melted on the top, turned over with the electrode and remelted, and repeated several times to insure complete melting and a reasonably cylindrical ingot suitable for subsequent working operations. Occasionally the arc may wander and puncture the top shell of the water-cooled hearth; this has been overcome by redesigning the hearth as shown at right of Fig. 2, so the top surface is now 1 in. thick except for depressions machined out to contain the charge and the getter. Cooling under these conditions seems to be adequate.

The only detectable change in analysis due to melting is a large reduction in hydrogen content – for example from 110 cc. per 100-g. electrodeposit to 8 cc. per 100-g. ingot. There is no detectable contamination from the copper

hearth, the tungsten electrode or the titanium getter. The ingots have a columnar structure with long axes of grains generally normal to the furnace hearth. Oxide particles are located at columnar grain boundaries and also form a substructure within the grains.

Hot Working

The original hot working schedule used at A.R.L. consisted of forging and swaging at 900° C. (1650° F.) and rolling in the range 600 to 900° C. (1110 to 1650° F.) The chromium was totally sheathed in steel sheaths to avoid contamination from the atmosphere and from contact with the tools (which would rapidly chill the small specimens then in use). The specimens were sealed into the sheaths under an atmosphere of argon to prevent entrapment of air between specimen and sheath. Specimens were stripped, filed to remove any surface defects, and resheathed between each working operation.

For forging and swaging, mild steel sheaths were used whose wall thickness was approximately one quarter of the diameter of the chromium specimen. Sheath thickness is quite important—particularly during swaging; if the sheath is too thin the rod will crack. Duplex sheaths were used for rolling – an inner mild steel sheath surrounded by an outer stainless steel jacket to provide greater strength to cope with the more severe deformation involved. After rolling, the specimen was stripped by removing the stainless steel jacket mechanically and dissolving the mild steel sheath in acid.

More recently we have rolled bare specimens. This results in some contamination from the atmosphere which, however, is very superficial at least for rolling temperatures not much above 700° C. (1300° F.)

Upsetting – One point of particular interest is that it was always necessary to commence by upsetting the cast ingot by forging normal to the long axis of the specimen; otherwise severe cracking occurred along the columnar grain boundaries.

Reductions in area of 15% were given during swaging, but no attempt was made to adopt a standard reduction between rolling passes. Quite severe deformation could be given by rolling in the temperature range mentioned above without frequent intermediate annealings.

Several attempts have been made, using different swaging conditions and temperatures as high as 1450 to 1500° C. (2650 to 2725° F.), to swage arc-melted ingots directly. However, severe cracking always occurred similar to that if ingots were forged without first upsetting.

Extrusion – Experience with other refractory alloys, notably the Nimonic series, has shown that extrusion is likely to be successful when other methods fail. This is due, presumably, to the fact that the hydrostatic component of the extruding stress tends to avoid tension at grain boundaries.

At D.S.L., 1000-g. ingots of pure chromium (1.5 in. diameter by 4.5 in. long) have been successfully extruded to 0.5-in. round bar. First the ingot is machined all over and then heated to 1200° C. (2200° F.) in a molten barium chloride bath. Sheathing is unnecessary, since the thin adhering film of salt provides excellent protection against atmospheric contamination. Furthermore, the heat loss during transfer from salt bath to extrusion press is not serious. The extrusion press has 250 tons capacity, and the operation takes approximately 1 sec. A glass lubricant between the chromium and the die is derived from a pad of woven soda-glass fiber placed over the opening before the billet is inserted.

Extruded chromium consists mainly of equiaxed grains and is brittle at room temperature as would be expected for reasons to be discussed later. Figure 3 shows the bar to have a banded structure, composed of longitudinal bands of recrystallized grains, the grains in alternate bands being of different size. In addition, bands of deformed material are present in the central sections of the bar.

Some preliminary experiments are being carried out at A.R.L. in which the die, die barrel, and plunger, which are made from graphite, are held at 1500° C. and the slug is dropped into place and extruded after a short soaking time to enable it to reach the operating temperature. In this work the back extrusion method is being used.

The Problem of Ductility

Hot worked, high-purity chromium, made into round rod or thin sheet as outlined above, was brittle after removing it from the sheath but ductile if the skin was etched away in acid! Some agency produced extreme brittleness in the surface layers which caused the whole specimen to fracture in a brittle fashion under bending stresses, even though the core was in fact ductile.

The possible agencies appeared to be nitrogen or oxygen from the air space between specimen

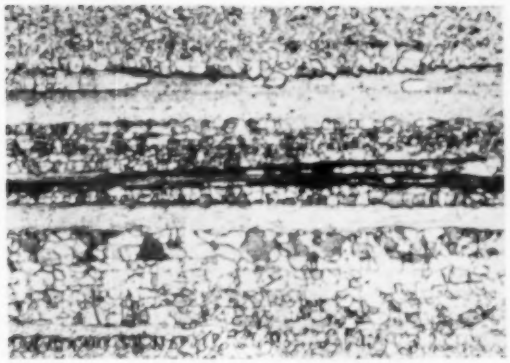


Fig. 3 – Structure at Center of 0.5-in. Extruded Bar of Pure Chromium. 25 ×. At center are thin bands of deformed material, apparently not recrystallized. Nearly all of the bar, however, is of longitudinal bands of recrystallized grains. Size of grains is different in alternate bands

and sheath, or iron or some other impurity absorbed from the sheath itself. Our investigations along these lines will now be briefly described.

Gaseous Impurities – It was found that small strips of ductile chromium became embrittled after heating in air at 700° C. (1300° F.) and remained brittle even after the thickness of the strip had been reduced a considerable amount by acid etching. To distinguish whether the oxygen or the nitrogen in the air were responsible, the experiments were repeated in the pure gases. We found that embrittlement of ductile chromium occurs on heating in nitrogen and the depth of embrittlement increases with time of annealing. On the other hand, specimens heated in oxygen were not appreciably embrittled and were ductile without etching the surface. Chemical analysis confirmed that the embrittlement resulting from heating in air is almost certainly due to nitrogen penetration. The dangerous concentration is on the order of 0.02% by weight. No nitride can be found by microscopic examination; hence the embrittlement was largely due to nitrogen in solution.

Surface condition is the second important factor influencing room-temperature ductility of chromium. As shown in Table I a strip of chromium, initially ductile at room temperature, became brittle if the surface was ground or coarse filed, but the original ductility was restored if a layer 0.001 to 0.002 in. thick were removed by acid etching, polishing with fine papers, or polishing electrolytically. Microscopic examination of taper sections of a filed specimen revealed a thin surface layer more heavily cold worked than the bulk of the sample, but no evidence of recrystallization or cracking.

Recrystallization – The above experiments were carried out at temperatures below which the metal recrystallized detectably.

Consideration was next given to the effect of recrystallization on the room-temperature ductility of chromium in bending. Specimens were rolled at 600° C. (1110° F.) and then annealed in their sheaths at various temperatures up to 950° C. (1750° F.). The sheath was removed and each strip was etched to a thickness of 0.035 in. to remove any contaminated material and then slit longitudinally to form two bend specimens. One of each pair was chemically etched and the other electrolytically polished until the specimens were 0.03 in. thick. Hardness and bend tests were made and the progress of recrystallization was followed by microscopic and X-ray examinations.

As shown in Fig. 4 no decrease in bend ductility was observed in specimens annealed at temperatures up to 850° C. (1560° F.), which corresponded to the onset of recrystallization. However, annealing at successively higher temperatures produced a progressive decrease in room-temperature bend ductility, and after complete recrystallization at 950° C. (1740° F.) the material behaved in a completely brittle fashion. Similar results were obtained in bend ductility tests on both electropolished and chemically etched specimens.

There is still some doubt that the above effect is due to recrystallization alone, because specimens of ductile recrystallized chromium have been produced by iron-plating the chromium to reduce to a minimum the impurities picked up during fabrication. Also, hydrogen-treated electrolytic chromium, which has an equiaxed grain structure, is ductile at room temperature.

Transition Temperature – The effects of the above three agencies have been confirmed by studying the

Table I – Effect of Surface Treatment

Condition	Hardness*	0.2% Proof	Ultimate	Elongation†
Ground and filed	208	—	89,000 psi.	0%
Acid etched	202	45,500	78,500	11
Electropolished	190	55,000	74,500	15

*Vickers diamond pyramid, 5-kg. load. †% on 0.5 in.

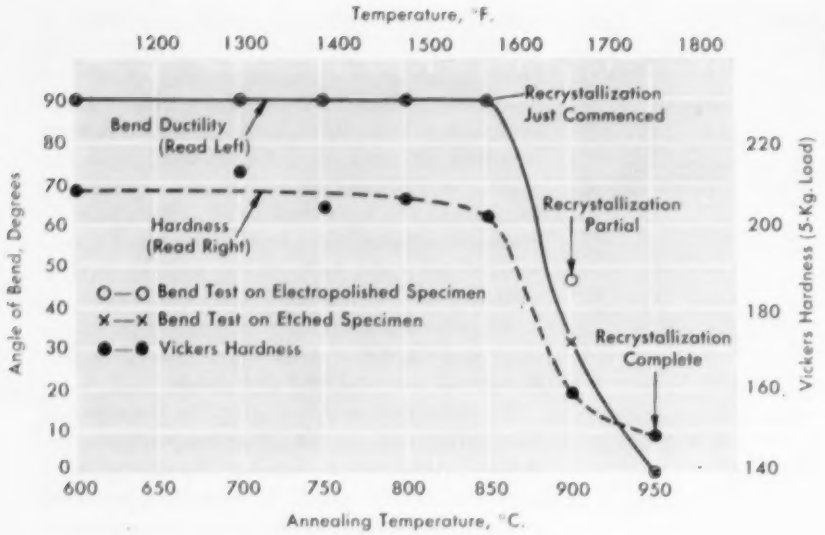


Fig. 4 – Effect of Recrystallization on Ductility. Specimens heated less than 850° C. bend through 90° on the test machine; they were all subsequently bent 180° without fracture

temperature range above which a sample can be bent and below which it is ductile. A summary of a large amount of work on pure chromium rolled into sheets at 600° C. (1110° F.) is as follows:

Treatment	Transition Temperature	
Electropolished	–42° C.	–44° F.
Electropolished and partly recrystallized	30	86
Electropolished and filed	90	194
Electropolished and fully recrystallized	135	275
Elecropolished and heated in N_2 for 16 hr. at 720° C. (1330° F.)	255	491

Ductility of Other Forms

Ductility of chromium in a few forms other than rolled strip has been tested. Hydrogen-treated electrodeposited chromium is ductile at room temperature. However, chromium as deposited and containing 0.2 wt. % O_2 and 0.002 wt. % N_2 was brittle at room temperature – as was less pure material. Heating to 450° C. in a vacuum to remove residual stresses and hydrogen did not reduce this brittleness, but electropolished specimens of as-deposited chromium of the above composition were ductile after heating to 850° C. (1550° F.) in a vacuum. If more than the above amounts of oxygen and nitrogen were present the specimens remained brittle after this treatment.

It seems therefore that electrodeposited chromium can be ductile if it is sufficiently pure, but it appears from our experiments that agglomeration of oxide film networks may be necessary. Relief of internal stresses alone may suffice, because a ductile sample has been obtained after vacuum treatment for 6 hr. at only 300° C.

As regards arc-melted chromium, electropolished longitudinal specimens of the above purity were invariably ductile but transverse specimens were sometimes brittle. This effect has not been examined closely, but it may indicate an orientation influence such as is found in cast molybdenum. Electropolished samples of forged and swaged material of the above composition were invariably ductile when tested at room temperature.

Summary

The main contribution of Australian workers in the field of chromium alloy research can be summarized as follows:

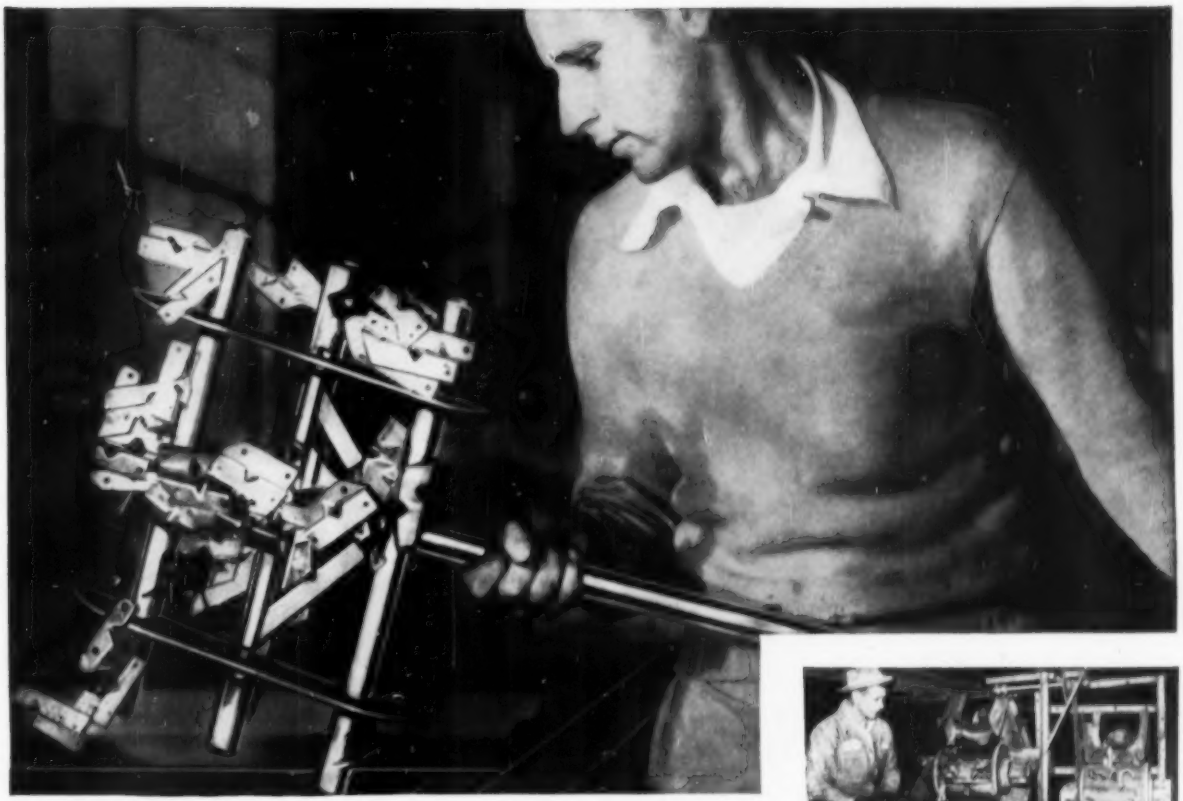
1. A method for producing extremely pure chromium in quantity.

2. Demonstrating that chromium is not inherently brittle at 70° F. and that the ductile-to-brittle transition can be depressed considerably below room temperature.

3. Elucidation of some of the factors producing embrittlement in chromium.

4. Extruding of chromium (and also some chromium-base alloys) without losing room-temperature ductility.

If these contributions are added to those from other sources, it becomes clear that the prospects for a ductile high-temperature alloy based on chromium, which is the principal aim of the Australian workers, are much brighter than appeared possible a few years ago.



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Approximate Strength of Jet Engine Alloys After Optimum Treatment

Inconel "X"; A.M.S. 5542, 5667 (Wrought)
70 Ni, 15 Cr, 7 Fe, 2.5 Ti, 1.0 Cb+Ta, 0.7 Al, 0.45 Si, 0.15 Cu, 0.07 C

Temp., °F.	Tensile Test: Strength, Psi.	Tensile Test: Elongation, % in 2 In.	Stress-Rupture: 100 Hr., Psi.	Stress-Rupture: 1000 Hr., Psi.
70	163,000	18		
1100	135,000	20	97,000	78,000
1200	128,000	15	76,000	60,000
1300	113,000	10	60,000	48,000
1400	93,000	11	45,000	32,000
1500	63,000	15	30,000	18,000
1600	42,000	25	19,000	9,000

Haynes 31 (X 40); A.M.S. 5382 (Cast)
56 Co, 25.6 Cr, 10 Ni, 7.3 W, 0.6 Fe, 0.5 C

Temp., °F.	Tensile Test: Strength, Psi.	Tensile Test: Elongation, % in 2 In.	Stress-Rupture: 100 Hr., Psi.	Stress-Rupture: 1000 Hr., Psi.
70	130,000	8		
1200	92,000	15	56,000	45,000
1300	82,000	11	49,000	37,000
1400	72,000	11	38,000	30,000
1500	61,000	13	28,000	23,000
1600	50,000	18	22,000	17,000
1700	40,000	21	15,000	12,000
1800	30,000	30	9,000	7,000

Waspaloy (Wrought)
56 Ni, 19 Cr, 14 Co, 4 Mo, 3 Ti, 1.7 Fe, 1.2 Al, 0.4 Si, 0.7 Mn, 0.05 C

Temp., °F.	Tensile Test: Strength, Psi.	Tensile Test: Elongation, % in 2 In.	Stress-Rupture: 100 Hr., Psi.	Stress-Rupture: 1000 Hr., Psi.
70	185,000	25		
1500			31,500	20,000
1600			19,500	
1400			55,000	33,000
1500	Vacuum Melted		37,000	22,000
1600			23,000	13,000
1700			13,000	6,000

M-252 (Wrought)
53 Ni, 19 Cr, 10 Co, 10 Mo, 2.5 Ti, 2.5 Fe, 1 Mn, 0.8 Al, 0.7 Si, 0.16 C

Temp., °F.	Tensile Test: Strength, Psi.	Tensile Test: Elongation, % in 2 In.	Stress-Rupture: 100 Hr., Psi.	Stress-Rupture: 1000 Hr., Psi.
70	172,000	20		
1300	135,000	9		44,000
1400	120,000	8		30,000
1500	100,000	10	27,000	15,000

S-816; A.M.S. 5534, 5765 (Wrought)
42 Co, 20.5 Ni, 20 Cr, 4.2 W, 4 Cb, 4 Mo, 3 Fe, 1.3 Mn, 0.6 Si, 0.4 C

Temp., °F.	Tensile Test: Strength, Psi.	Tensile Test: Elongation, % in 2 In.	Stress-Rupture: 100 Hr., Psi.	Stress-Rupture: 1000 Hr., Psi.
70	150,000	32		
1100	115,000	21	91,000	77,000
1200	110,000	22	65,000	52,000
1300	101,000	25	47,000	36,000
1400	88,000	32	34,000	25,000
1500	70,000	33	24,000	17,000
1600	50,000	20	15,000	10,000

Haynes 25 (L 605); A.M.S. 5537 (Wrought)
51 Co, 20 Cr, 15 W, 10 Ni, 1.6 Mn, 1.6 Fe, 0.6 Si, 0.08 C

Temp., °F.	Tensile Test: Strength, Psi.	Tensile Test: Elongation, % in 2 In.	Stress-Rupture: 100 Hr., Psi.	Stress-Rupture: 1000 Hr., Psi.
70	150,000	50		
1200	96,000	26	70,000	58,000
1300	82,000	14	52,000	42,000
1400	69,000	12	37,000	27,000
1500	54,000	15	24,000	17,000
1600	43,000	22	16,000	11,000
1700	33,000	25	10,000	7,000
1800	25,000	27	8,000	4,000

Haynes 21 (Vitallium); A.M.S. 5385 (Cast)
62 Co, 28 Cr, 5.5 Mo, 2.5 Ni, 1.7 Fe, 0.28 C

Temp., °F.	Tensile Test: Strength, Psi.	Tensile Test: Elongation, % in 2 In.	Stress-Rupture: 100 Hr., Psi.	Stress-Rupture: 1000 Hr., Psi.
70	108,000	5		
1300	76,000	12	38,000	24,000
1400	71,000	15	28,000	17,000
1500	62,000	20	22,000	14,000
1600	53,000	23	18,000	12,000
1700	40,000	26	13,000	10,000

N-155; A.M.S. 5376 (Cast) 5767, 5768 (Wrought)
30 Fe, 21 Cr, 19 Ni, 19 Co, 3.2 Mo, 2 W, 1.64 Mn, 1.1 Cb, 0.38 Si, 0.12 N, 0.12 C

Temp., °F.	Tensile Test: Strength, Psi.	Tensile Test: Elongation, % in 2 In.	Stress-Rupture: 100 Hr., Psi.	Stress-Rupture: 1000 Hr., Psi.
70	120,000	40		
1200	80,000	32	50,000	38,000
1300	70,000	32	37,000	29,000
1400	60,000	32	26,000	20,000
1500	50,000	33	18,000	13,000
1600	35,000	34	13,000	
1700	25,000	35	8,000	

A-286 (Modified Tinidur); A.M.S. 5735 (Wrought)
53 Fe, 26 Ni, 15 Cr, 2 Ti, 1.35 Mn, 1.2 Mo, 0.9 Si, 0.3 Va, 0.2 Al, 0.05 C

Temp., °F.	Tensile Test: Strength, Psi.	Tensile Test: Elongation, % in 2 In.	Stress-Rupture: 100 Hr., Psi.	Stress-Rupture: 1000 Hr., Psi.
70	150,000	23		
1000	132,000	21	99,000	88,000
1100	125,000	18	81,000	72,000
1200	117,000	10	63,000	45,000
1300	91,000	7	45,000	30,000
1400	60,000	9	29,000	17,000
1500	32,000	22	15,000	8,000

Discaloy 24; A.M.S. 5733 (Wrought)
54 Fe, 26 Ni, 13 Cr, 3 Mo, 1.8 Ti, 1 Mn, 0.9 Si, 0.16 Al, 0.08 C

Temp., °F.	Tensile Test: Strength, Psi.	Tensile Test: Elongation, % in 2 In.	Stress-Rupture: 100 Hr., Psi.	Stress-Rupture: 1000 Hr., Psi.
70	143,000	22		
1000	119,000	17	87,000	73,000
1100	115,000	17	72,000	57,000
1200	100,000	17	56,000	43,000
1300	82,000	18	40,000	28,000

Refractaloy 26; A.M.S. 5760 (Wrought)
37 Ni, 20 Co, 18 Cr, 17 Fe, 3 Mo, 2.8 Ti, 0.8 Si, 0.7 Mn, 0.2 Al, 0.05 C

Temp., °F.	Tensile Test: Strength, Psi.	Tensile Test: Elongation, % in 2 In.	Stress-Rupture: 100 Hr., Psi.	Stress-Rupture: 1000 Hr., Psi.
70	152,000	15		
1200	130,000	10	80,000	63,000
1300	120,000	5	60,000	46,000
1400	106,000	6	42,000	31,000
1500	79,000	11	27,000	18,000

Timken 16-25-6; A.M.S. 5727 (Wrought)
50 Fe, 25 Ni, 16 Cr, 6.3 Mo, 1.9 Mn, 0.6 Si, 0.15 N, 0.08 C

Temp., °F.	Tensile Test: Strength, Psi.	Tensile Test: Elongation, % in 2 In.	Stress-Rupture: 100 Hr., Psi.	Stress-Rupture: 1000 Hr., Psi.
70	135,000	20		
1000	98,000	23	80,000	72,000
1100	95,000	21	62,000	50,000
1200	85,000	19	45,000	33,000
1300	74,000	19	32,000	22,000
1400	58,000	22	20,000	14,000
1500	42,000	24	14,000	9,000

A.I.S.I. Type 347 Stainless Steel (Wrought)
71 Fe, 18 Cr, 10 Ni, 0.7 Cb, 0.07 C

Temp., °F.	Tensile Test: Strength, Psi.	Tensile Test: Elongation, % in 2 In.	Stress-Rupture: 100 Hr., Psi.	Stress-Rupture: 1000 Hr., Psi.
70	90,000	50		
1100	57,000	39		30,000
1200	50,000	44		17,000
1300	40,000	51		11,000
1400	31,000	61		7,000

A.I.S.I. Type 321 Stainless Steel (Wrought)
72 Fe, 18 Cr, 9 Ni, 0.6 Ti, 0.07 C

Temp., °F.	Tensile Test: Strength, Psi.	Tensile Test: Elongation, % in 2 In.	Stress-Rupture: 100 Hr., Psi.	Stress-Rupture: 1000 Hr., Psi.
70	85,000	55		
900	56,000	37		
1000	53,000	40		
1100	50,000	43		27,000
1200	44,500	48		17,500
1300	36,500	56		10,000
1400	28,500	64		5,600
1500	22,000	73		3,700

Timken 17-22-AS; Cyclops 14 MV (Wrought)
97.7 Fe, 1.2 Cr, 0.5 Mo, 0.3 C, 0.25 V

Temp., °F.	Tensile Test: Strength, Psi.	Tensile Test: Elongation, % in 2 In.	Stress-Rupture: 100 Hr., Psi.	Stress-Rupture: 1000 Hr., Psi.
70	153,000	18		
900	118,000	68	107,000	
1000	108,000	70	75,000	62,000
1100	93,000	76	40,000	23,000
1200	75,000	72	15,000	7,000

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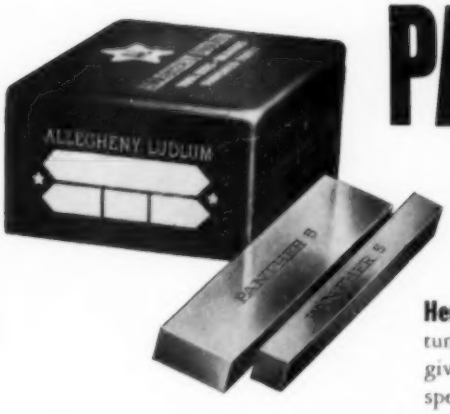

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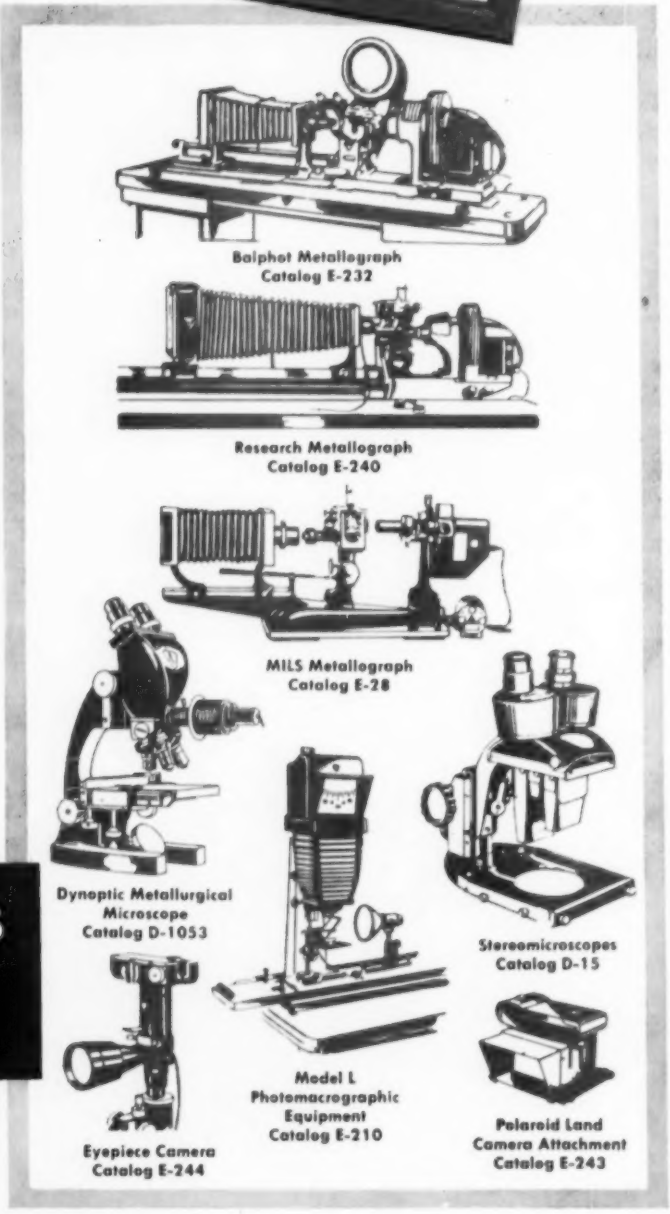

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Metalworking in Colombia, South America

*By GERALD X. DIAMOND**

One South American state, rapidly expanding in population and attempting to escape an economy based on coffee exports, still depends for the most part on the primitive metalworking arts, yet extreme contrasts occasionally appear, such as an almost automatic factory for cosmetic tubes and one completely integrated steel plant. (A general)

COLOMBIA has been called a "fabulous land, full of emeralds and gold, poisonous snakes and tall tales", and nobody has exaggerated. Examples of the gems and precious metals can be seen at a dozen museums throughout the country. Poisonous snakes are easy to find—generally as handbags in fashionable shops in Bogota, Medellin or Cali. The tall tales are a saga of the metals industry which makes a 1955 metallurgist weep!

Perhaps it would be well to tell American metallurgists where Colombia is situated. If you look at a map of South America you will find it the northernmost in the tier of countries washed by the Pacific. In fact Colombia starts at the Caribbean and passes Panama (which was once part of it) down to the equator; it is some 800 miles from north to south. The western strip, about 300 miles broad, is occupied by rugged Andean mountains; to the east is a 400 x 600-mile rectangle of low country (500 ft. elevation) draining into the Orinoco and the Amazon. The southern part of this is dense tropical forest; the northern part is semi-desert prairie. This 440,000 sq.mi. of territory is inhabited by 11,000,000 people (about the same population as California on three times the land). Nearly all of them live in the mile-high Andes valleys and plateaus.

Nearly 900 metalworking companies are listed in the National Directory of Colombia, but only a handful can be faithfully described by the word "industry". Most of them import nearly all their raw materials, and manufacture products which return a high yield on the investment. For example, metal kitchen and restaurant ware and office furniture are made in Medellin and Bogota

*Department of State, Bogota, Colombia. Mr. Diamond, formerly assistant director of research of Metcut Research Associates of Cincinnati, is now holding one of the Buenos Aires Convention Fellowships administered by the Institute of International Education. The information was gathered while visiting over a hundred metalworking plants. Opinions are the author's and not the official views of the U.S. Department of State.

Fig. 1 — "Assembly Line" of Talleres Apolo, Manufacturers of Sugar-Cane Crushers. Small cast iron rolls and driving gears are shrunk on steel shafts

from imported tube and sheet steel. At least 100 shops throughout the land manufacture metal window frames and wrought iron grillwork from imported profile and bar stock. European angles, channels and I-beams are widely used for structural work, many small companies specializing in fabrication. Nails are cold headed in Cali and Barranquilla from imported wire; toothpaste tubes are extruded in Palmira from imported tin (despite the existence of large unworked ore deposits); pots and pans are spun in Medellin and Baranquilla from imported aluminum disks. Even the steel mill in Medellin, producing 35 to 40 tons of concrete reinforcing rod and steel castings daily, uses scrap steel as its only raw material — demolition scrap which at one time had been imported as finished products. Colombia does possess one integrated iron and steel plant at Paz del Rio, a little west of Bogota — more about this later.

The Colombian metal industry is therefore primitive, by standards known in the United States. Inexpensive labor, small volume, and wide variety of products are powerful arguments against the capital investments required for mechanization. Though many progressive firms emphasize quality, the product of the large majority is of poor quality. The aim is for low costs and high profit.

Technical education is strictly limited. Furthermore, the teaching faculties are overloaded with graduates with no field experience, using the same out-dated texts they studied themselves. Modern books in Spanish for training in mechanics and foundrywork are scarce. Technicians who have taken correspondence courses are in fact more successful than technical school graduates. Metallurgy courses, though required in several schools, lack competent professors and demonstration or laboratory equipment.

The overwhelming majority of metalworking firms employ no technical assistants. University graduates command little better salaries than average laborers, and may be found earning only 800 pesos ($200) a month after several years' employment. In the plants employing foreign technicians, Europeans are often preferred because they will work for less than Americans, and better accept the existing limitations.

Foundry Industry

Nearly half of the firms in the metals industries in Colombia are foundries, or do their own foundry work. Blueprints, specifications, alloying and heat treatment are practically unknown. Machinery repair is the big business. A very few products occupy virtually all "production" foundries: coffee depulpers (machines for removing the pod from delicate coffee beans), sugar cane crushing mills, Pelton water wheels, and sewer and aqueduct manhole covers.

At Talleres Apolo, in Medellin, hundreds of cane crushers are produced yearly. Frame, crushing rolls and gears are of cupola iron, the cast rolls being shrunk on steel axles (Fig. 1). Copper alloy bearings are cast separately, from scrap metal. Because of the poor surface quality of castings and lack of modern tools, machining is very costly. Apolo is an exception in Colombia, since it uses both coke and flux for cupola opera-

tions. Only iron scrap and imported pig iron are used; there is no control of carbon and silicon, yet the iron must be gray for machinability.

The majority of foundries – even large ones – use no flux, ferro-alloys, or additives of any kind; many melt directly in the ladle! At one small foundry I saw the owner load his "cupola" – a mud-lined oil drum fired from the top by an air blast – with wet coal and build a wood fire on it. The charge was one old automobile engine, whole, including zinc carburetor, copper gasoline lines, glass wool fuel filter, alloy steel transmission gears, white iron piston rings, and porcelain spark plugs. The radiator assembly– complete with rubber hose – was melted down separately for "bronze" bearings!

Supplying most of the nonferrous metals used in Colombia is a large company named Juval, Inc., in Bogota. Here scrap metals are collected and melted to ingots – unfortunately, without chemical control of composition, and with no metallurgical personnel to govern operations.

In my travels I found only one foundry which was operating a modern cupola – that of Landers-Mora and Co. It produces corn-grinders of excellent quantity and quality. An American metallurgical engineer is the chief technician. The firm also makes pressure cookers (widely used in Colombia, since most cities are over a mile above sea level) of a quality equal to those made in the United States.

At the de Muna plant, near Bogota, cast iron is made from steel scrap in electric furnaces with close laboratory control of metal and sand. The chief products, sewer pipe fittings and sewer tops, represent only a small part of the firm's yearly business of machinery repair. Also at the steel mill in Medellin, galvanized malleable iron pipe fittings are made from electric-furnace iron by semi-mass production methods. This firm, by the way, is the only one in Colombia making pipe fittings, and one of three foundries using molding machines.

Bicycle Manufacture

In the city of Cali, Fabrica de Bicicletas Monark operates a modern factory and employs Swedish technicians, making bicycles especially designed for the unpaved Colombian roads. Precut steel tube and sheet are imported from Sweden, along with semi-manufactures, such as ball bearings, spokes, and sprocket gears. Electroplating of wheel rims and handlebars is done by a neighboring firm, Industrias Metalicas, one of the largest manufacturing companies in the country, employing over 250 workers and operated by American technicians. Chromium-plated home and office furniture is mass-produced, though much more hand labor is employed than necessary. A recent installation of a Yoder tube mill has emancipated this firm from one of its most troublesome imports.

Unfortunately, few other light industries are as modern. Over a dozen fairly large manufacturers make money by turning out a variety of furniture and tricycle designs, mostly by hand

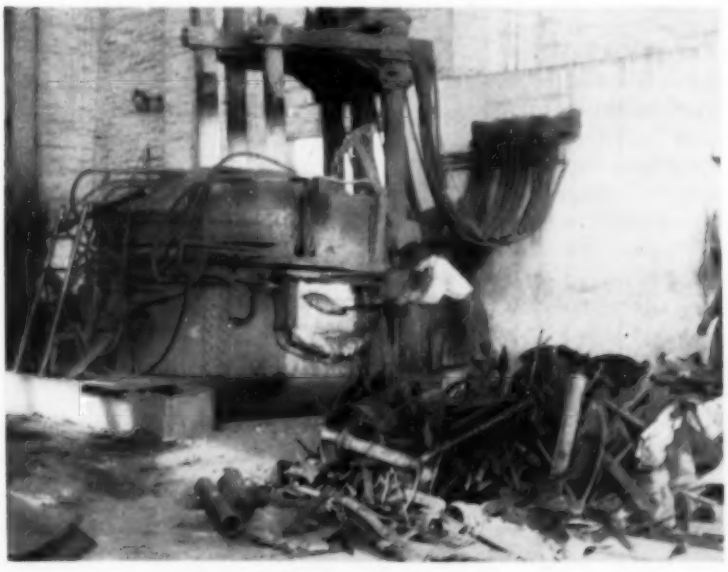

Fig. 2 – Steel Melting Furnace at Medellin Ready for Charging With Country Scrap

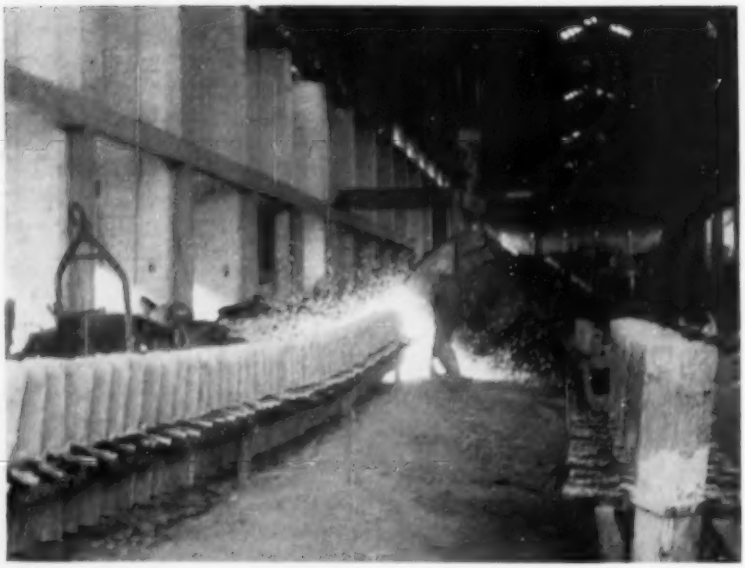

Fig. 3 – Small Ingots Top Poured Into Split Molds

labor, and often on home-made machinery. Lack of die making and heat treating facilities affects production only slightly. Dies are laboriously carved out of wrought iron plate or block. When the soft iron wears too much it is replaced.

One large and unusual business is the manufacture of roll-up curtains of steel bar and profile stock for store windows and doors. (Few shops have any other doors.) Soft iron bar stock is bent to form by hand and assembled with hand-made clips. Installation is included in the price, since each curtain is made to order.

Extrusion and Stamping

In the sleepy agricultural town of Palmira, it was no small surprise to find a modern little factory, Industrias Oliver, extruding collapsible tubes for a number of cosmetic and drug firms in nearby Cali. Mounted by an American engineer, the factory is virtually automatic. Carbide dies are used; annealing and painting are done on conveyors. One of the chief diemakers is a girl – a most remarkable breach of Colombian custom.

Automobile licenses in Colombia are a thin steel plate to which are riveted 20 to 24 aluminum letters and monograms. Cheap labor does it. Toys are manufactured in Bogota of tin plate, deep drawn in dies fixed to a job printing press. Automobile oil is the lubricant. Dies are made from nondescript toolsteel, filed to dimensions and fitted by eye, with no micrometers, calipers or verniers.

Hand forged farming implements are made in great quantity. One operation resembled what I would imagine would be a prosperous blacksmith shop of the 1600's, with its line of bellows, fires, anvils, and bearded blacksmiths hammering red iron with showers of sparks into axes, sickles, crowbars, and horseshoes. In contrast, but a few streets away was a zipper factory, stamping them out by the million on fully automatic machinery. An expert diemaker spent full time to maintain operations, but this time it was English technology behind the work.

Steel Manufacture

Prior to the recent opening of the Paz del Rio plant, the steel plant at Medellin represented the most "modern" in Colombia. Even here, the notable thing is the production of malleable iron pipe fittings mentioned above. Steel for merchant bar is made from country scrap in a 1-ton electric furnace and, as can be seen in Fig. 2, there is little selection of raw material. Ingots are about 4 in. square, cast in split molds (Fig. 3), stripped, stored and reheated later. Blooming and rod mills are hand fed; principal product is ½-in. reinforcement rod, replete with inclusions, seams and scale. Tensile tests may be made, if there is any demand, some days or weeks after shipment.

Paz del Rio – Colombians are rightly proud of the integrated steel plant, Empresa Siderurgical Nacional, near Bogota, operating on nearby iron ore and coking coal. The countryside there-

abouts is so rich in raw materials that one engineer suggested simply plowing the mountains together, spreading liberally with dolomite, and setting them on fire. Then with the aid of a friendly earthquake the land could be tilted to pour off the iron!

Empresa is South America's third steel mill. Planning started as early as 1938. Financing was very difficult. Over $27,000,000 was raised by taxation and by stock sales in Colombia, $25,000,000 was loaned by French firms which furnished structures and machinery, and another $11,000,000 from similar firms in West Germany. Ground was broken in 1951 and operations started in October of 1954.

Along with the adjacent mining operations, the plant is well balanced with coke ovens, a 500-ton blast furnace, three 30-ton bessemer converters, one 30-ton electric furnace (intended to remelt own scrap from the finishing mills) and rolling mill train for rails, small structural shapes and billets. Billets from this mill are reheated and made into wirebar in a looping mill of four stands, and processed immediately in a continuous mill to wire rod about ¾ in. diameter. This product is coiled automatically and conveyed by overhead hangers to the wire mill for drawing, annealing, galvanizing, and then to appropriate machinery for making barbed wire and nails. Electric energy (35,000 kw.) is generated by steam turbines and standby diesel plant. All furnaces are equipped to burn either coke oven gas, blast furnace gas, powdered coal, or, if necessary, all three. At present, powdered coal is the most important source of power.

Fig. 4 — Electric Furnace at Colombia's National Steel Plant Receiving a Top Charge of 10 Tons of Railroad Scrap

At the time of writing (September 1955) the Empresa plant has not yet shaken down into steady operation. Many reasons have been given. Although designed to furnish about half of the country's needs as estimated in 1950, population and industrialization are increasing so rapidly that large extensions are even now under consideration. Lack of a sound finance plan is probably the greatest obstacle. Expansion of demand and slow start at Empresa result in a situation where imports of metallic materials are still about as high as ever!

The Near Future

From what has been said it may be surmised that absence of technical assistance and dependence upon imports of semifinished materials characterize Colombia's metal industries. Despite these faults, the future of this land, the Switzerland of South America, is bright. Colombia has too long been dependent upon coffee for its national income; limitations to imports have forced investors to begin to look toward the unlimited wealth of raw materials in Colombian soil. The steel enterprise at Paz del Rio, financed largely by taxes, is the first step in this direction. Numerous successful firms employing U.S. technology are earning recognition as ways to make money more securely than in coffee growing. Government aid to technical schools in the form of new directors (exclusively European, so far) and to encourage foreign study will provide the new blood so badly needed. A modern metallurgical laboratory, now under construction at the University of Valle, will provide badly needed practical training as an adjunct to its metallurgy courses.

Wear of Metals by Sand Erosion

*By WERNER A. STAUFFER**

A 15-hr. test is able to determine sand erosion of various constructional materials to ±5% reproducibility and the results correlate with experience on hydraulic turbines. With soft steel equal to 1.0, "Ni-Hard" = 5.5, hardened high-chromium steel = 6.0, hard chromium plate = 12.0, welded "Stellite 6" overlay = 18.0, and sintered carbides may be as high as 92. (Q 9)

THE SWISS FIRM Escher Wyss Machinenfabriken A.G. has long specialized in power plant machinery and various kinds of large rotating equipment and its auxiliaries, such as water, steam and gas turbines, turbo pumps and compressors, heat pumps and centrifuges. During this time it has built many large units for hydroelectric plants in various parts of the world. These are primarily Kaplan screw-type turbines for low-head, Francis reaction turbines for medium-head and Pelton impact water wheels for high-head operation.

The water going through hydraulic turbines almost always carries sand, rock meal (glacier debris) or earthy substances, especially when it comes directly from streams rather than from dams or lakes. Wear caused by such solid components in water is called sand erosion. An example of wear on Pelton buckets is shown at the head of this article; its characteristic is the wavy, semi-matte surface of the eroded areas. Parts exposed to a stream of water carying sand, such as bucket wheels and guide rings, control members and shutoff gates, may become unusable in a short time through excessive wear.

The wear on operating machinery depends on

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many factors, such as sharpness and hardness of the sand particles, chemical corrosion by the water, the pressure or velocity of the stream, and the nature of the metal itself. Service tests give a great scatter of results because such a multitude of factors are operating. Furthermore they are costly in time and money. Nor can results found in one locality be applied to conditions elsewhere, either qualitatively or quantitatively.

The alternative of testing scale models has not been fruitful. Service conditions are hardly ever reproducible. It is immediately clear that the "similarity requirement" cannot be satisfied in sand erosion testing, since the uncertainties arising are so great that not even those quantities which directly affect the wearing process are known or can be measured.

Despite the fact that the problem has been so complicated that a successful attack upon it has not been achieved until a few years ago, it nevertheless is of the greatest commercial importance to evaluate the wear resistance of materials in this type of service.

Nature of Wear – Quite generally, all the seven or eight kinds of wear obviously involve the removal of material from the working surface. Protruding tiny peaks of metal may be sheared off, or they may weld together momentarily on surfaces which glide upon one another so that individual particles are torn away. Wear is usually associated with high contact pressures. For the most part, the wearing surfaces then deform and cold work, and strengthen to a depth which penetrates somewhat into the material, and which may increase the wear resistance. Destruction through wear may also be caused by high alternating stresses leading to spalling and local chipping.

With sand erosion destruction results from the impact of solid particles whereby particles of metal are broken off through the large shear forces arising. The average contact pressure is admittedly slight, but the specific contact pressure under sharp points or edges of sand grains nevertheless is great, and there the local stresses exceed the ultimate strength of the material.

Existing laboratory tests will give, under apparently similar conditions, differences in results amounting to one hundred fold, frequently associated with the experience of the operator and minute, unnoted differences in the conditions of testing. It is not sufficient to control rigidly the velocity of the test pieces, the pressure, the chemical composition of two materials in contact and the testing machine system.

Therefore it was our aim—and it has been achieved in the equipment to be described – to construct a testing machine which can differentiate various materials with respect to their wear resistance in a way which coincides with the experience gathered through service, and distinguish definitely the poor from the good materials.

Fig. 1 – Grinding Pot Device

M – Motor
B – Domed base
H – Houisng for shaft
HP – Horizontal plate
S – Samples
G – Guard
P – Mortar or pot

An important factor is also the simple geometry of the test piece, allowing it to be easily made from hard materials, difficult to machine.

The Mortar or Grinding Pot

Some years ago, at the suggestion of the writer, the materials laboratory of Escher Wyss started working with a device which has since proved its worth in avoiding the above-mentioned difficulties with earlier testing machines. The metals to be tested are simple stirring fingers, driven around in a pot of slurry, abrasive in water.

Figure 1 is a photograph of the equipment. A motor M with vertical shaft is mounted at the rear of the domed base B. In front of the motor is attached a housing H for a vertical shaft, at the bottom of which is a horizontal plate HP. Through four holes in this plate, symmetrically placed near its periphery, are dropped the pin-like samples S, held firmly by the lugs shown on top of the pate. Shaft and plate can be rotated at any desired speed between 200 and 5000 rpm. in 14 steps by a wedge-type belt drive contained in the guard G at top.

The mortar or pot P in the operator's hands is filled (with a mixture of two parts of river sand, or other granular abrasive as chosen, and one part tap water) to where the plate HP is just covered when the pot is attached to the upper support by a bayonet lock. In routine tests the spindle rotates at 730 rpm., and since the specimens travel around in a circle of 79-mm. radius (3.11 in.) they have a linear speed of 5.83 m. per sec. (1150 ft. per min.). The relative velocity between sand and test specimen is, of course, substantially less, since the sand-water mixture rotates in the same direction. Duration of the experiment is 15 hr., interrupted after 1 hr., 3 hr., and 7 hr. During the latter two interruptions the pot and contents are cooled by immersion in cold water; otherwise, the temperature may rise above boiling. During each pause and at the end of the experiment, the specimens are weighed; the sand is washed, dried, replenished to its original weight for the continuation of the experiment and water is added to the established quantity. These measures proved necessary, since some of the sand grains themselves will fragment during the experiment, and unless the debris or silt is removed the wear rate is reduced. The specimens are marked on the clamped end so they are always replaced in the same location and orientation.

In each run there are three identical test pieces of the steel or alloy under investigation. The fourth position is occupied by a reference specimen of the same size made of plain carbon steel for case hardening (corresponding to standard St C 16.61) annealed to Vickers 130 hardness by diamond pyramid. Figure 2 gives dimensions of the test piece in mm.

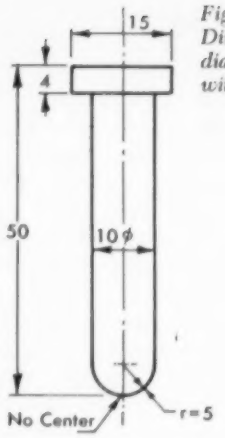


Fig. 2 – Standard Test Piece. Dimensions in mm. (0.394 in. dia. by 2 in. long). Finish is with 280-grit emery paper

Average weight loss of the three specimens may be plotted against time, as shown in Fig. 3 for five representative materials. For quantitative evaluation of such data we use the formula

$$C = L_n \cdot W \cdot V_n \div L \cdot W_n \cdot V$$

where C is the coefficient of resistance to wear, L and L_n are the loss in weight of average test piece and reference standards respectively, W and W_n are the original weight of average test piece and reference standard respectively, and V and V_n are the original volume.

In most instances the test pieces conform to the dimensions of Fig. 2, so $V = V_n$ and the formula becomes $C = L_n \cdot W \div L \cdot W_n$.

Since this formula relates the abraded volume of a material under examination to the abraded volume of the reference standard (annealed St C 16.61) we have come to use a resistance number R to compare various materials, one to another. R is the inverse ratio of abraded volume of reference standard to abraded volume of test piece. For example, if a 10% tin bronze in cast condition, Brinell 84, wears 1.4 times as fast as the standard, its resistance number R = 0.71. Again, if a welded Stellite overlay, Rockwell C-43 hard, wears only 5.5% as fast as the reference standard, its resistance number R = 18.0.

Notes on the Wear Test

Reproducibility – The reference test piece enables us to narrow the scatter of results. The requisite is, in any event, that the reference test piece does not differ excessively from the material

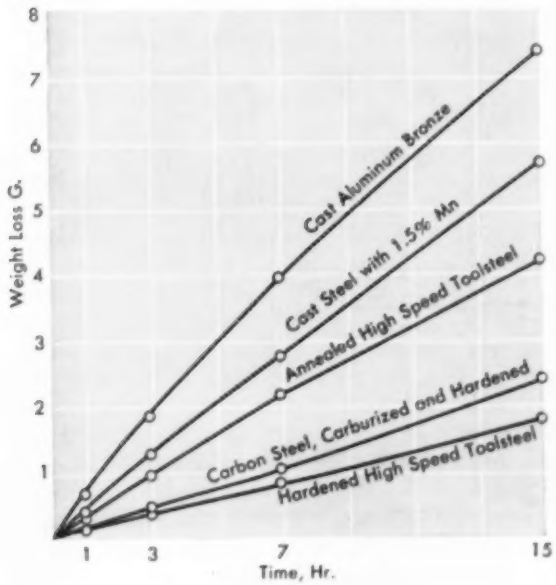
under test with respect to condition and wear resistance. Otherwise, one obtains high deviations through the influence of the test pieces, one on another. When materials deviate greatly from the reference material it is better to compare them with an average value for wear of reference specimen obtained from all the previous experiments run under standard conditions of speed, abrasive mixture, and so on.

A number of control experiments performed with various materials gave a maximum scatter of about ±5% of the average. If the results on all the individual test pieces be studied, the maximum deviation from the grand average amounts to ±10%.

Hardness of Sample – Although it is commonly known that sand erosion is less severe on hard metals than on soft, it does not follow that a given alloy or material, treated or formulated to a higher hardness than another, will have a higher wear resistance number, R. For example, the following cast tin bronzes have R's which fall within the limits of experimental error:

% Sn	Brinell Hardness	R
6	42	0.77
10	84	0.71
14	117	0.70
16	125	0.74
21	178	0.78

Fig. 3 – Weight-Loss Curves for Five Representative Metals Ranging From Fairly High to Low Resistance to Sand Erosion



Surface Finish – Standard finish on test pieces is with 280-grit emery paper. To investigate the effect of surface finish we prepared companion specimens, rough turned with prominent tool marks, (*a*) in the standard steel (St C 16.61), (*b*) brass, Vickers 138, a material with low wear resistance, and (*c*) a 12% Cr steel with 2.5% C, Vickers 535, having high wear resistance.

A notable difference in wear occurred early in the test runs. Indeed, after the first hour, the rough specimens lost 2 to 8% more weight than the smooth specimens, yet the resistance numbers of the brass and the chromium steel remain practically unaffected. Accordingly, the surface condition does not play any great role.

Speed of Rotation – Similarly, experiments on the three materials just mentioned were made with the plate running at 280, 560 or 730 rpm., the last mentioned being the standard. As would be expected, the wear expressed as weight loss is strongly dependent upon speed of movement through the abrasive. The weight losses correspond approximately to the third power of the ratio of the revolutions per minute. Nevertheless the resistance number remains practically constant at all speeds.

Nature of Reference Standard – To clarify whether St C 16.61 can be used for reference specimens for very soft and very hard materials, standard tests were run on four materials of widely different resistance to sand erosion:

High purity 99.99% aluminum ("Raffinal"), Vickers 22,	R=0.18
St C 16.61 (the standard), Vickers 130,	R=1.00
Nickel steel, Vickers 250,	R=1.53
Hardened C-Cr steel (2.5% C, 12% Cr), Vickers 535	R=2.50

The difference in resistance numbers for steels is not very great. Therefore, we consider St C 16.61 to be suitable for most materials, especially such as do not exhibit either extremely low or extremely high resistance.

For materials with low resistance numbers and especially for nonmetals such as wood, synthetics and rubber, we use Raffinal at lower speed and shorter time. The resistance number of Raffinal was compared with St C 16.61 at 280 rpm. and evaluated at 0.11, and this has been adopted as the conversion factor for such tests on these materials.

As reference standard for materials with very high resistance numbers, however, sintered carbide is used.

Abrasive – To determine the effect of the granular abrasive the four previously mentioned metals were tested in saw dust, loam, lime sand, ground white iron, quartz, corundum and silicon carbide. Results are summarized in Fig. 4, wherein the Vickers hardness of the mineral matter was calculated from the Moh hardness:

$$\text{Vickers hardness} = (1.43 \text{ Moh's hardness})^3$$

In Fig. 4, the experimental points and light lines connecting them are averaged by the heavier dashed smooth curve. Hardnesses of the tested materials and the standard are also given.

As may be seen, the resistance number depends upon the hardness of the abrasive. If the abrasive is soft, all three materials showed practically the same high wear resistance. The latter diminishes rapidly with increasing hardness of the abrasive and finally remains practically constant. Materials like aluminum and brass wear as rapidly (in comparison with annealed carburizing steel) in any abrasive harder than lime sand. Harder metal (hardened high-chromium, high-carbon steel) wears at approximately equal rate in comparison with annealed carburizing steel in any abrasive from loam to ground white iron, but much more rapidly in harder abrasives. The performance of the material with respect to wear, therefore, can vary considerably in accordance with the condition of the abrasive. Its grain size also has an effect. Resistance numbers decrease with decreasing grain size and the weight loss diminishes strongly. This is the reason for screening fines out of the abrasive at intervals during the test.

Resistance Data

Condition of test pieces of five materials, from extremely resistant to quite abradable, are shown in Fig. 5. The two at the left were short runs at slow speed. Some definite values taken from tests on more than 150 materials in various conditions are listed below.

White Metals – As would be expected, the white metals and their alloys have poor resistance to sand erosion. As has been noted, high-purity aluminum ("Raffinal") with 22 Vickers pyramid hardness has a resistance number of 0.11. A magnesium alloy of 17,000-psi. tensile strength has R = 0.13. A zinc alloy known as "white bronze" with Brinell hardness of 42 has R = 0.18. The aluminum alloy "Avional" with 54,000-psi. ultimate has R = 0.50.

Copper Alloys – Copper and copper alloys, cast and wrought, have R's ranging from 0.42 for cast brass, Vickers 154 hard, to 0.93 for a wrought copper-nickel alloy with 135,000-psi. ultimate strength. Cast copper (R = 0.75) and the tin bronzes (R = 0.70 to 0.78, as noted in the discussion above on effect of hardness) are near the top.

Cast Irons – Gray cast irons for machine parts, ductile cast iron, pearlitic cast iron and "Ni-Resist" of widely different tensile strengths (20,000 to 40,000 psi.) resist sand erosion not much better than copper alloys, having R from 0.70 to 0.90. Various alloyed cast irons show higher resistance numbers, especially ductile cast iron, unannealed

Fig. 4 – Relationship of Hardness of Abrasive Grain to Resistance Number of Aluminum, Brass and Hardened Chromium Steel

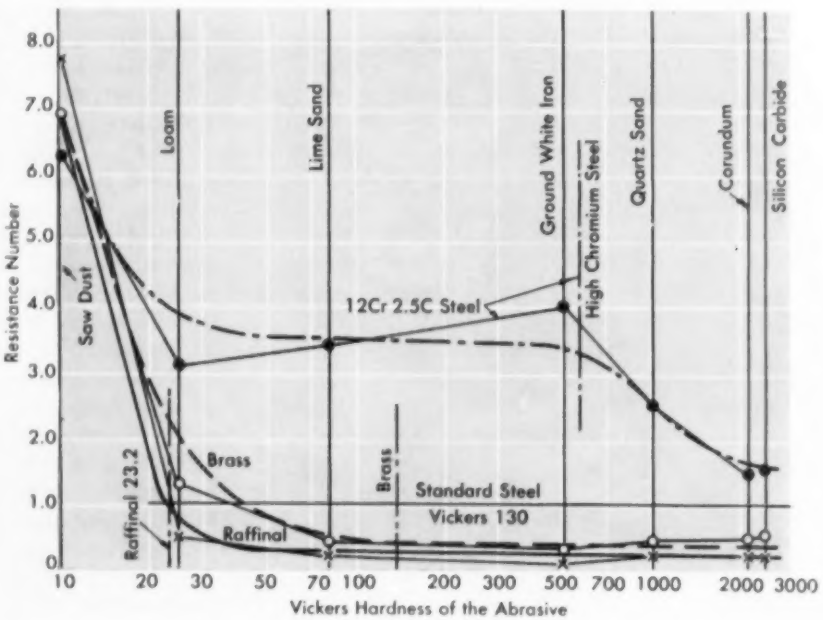


Fig. 5 – Condition of Samples After Test. Left to right: sintered carbide, annealed toolsteel, 18-10 Cr-Ni austenitic steel, cast zinc alloy, cast magnesium alloy. The latter two were run for a short time at slow speed

(R = 1.3), as well as various mottled and white irons. So-called "wear resistant cast irons" are much better; one with Brinell 500 had R = 2.2; another with Vickers 409 had R = 3.0; and a third with Vickers 514 had R = 4.2. White pig iron (Brinell 420) had high resistance (R = 3.65) but the highest of all is "Ni-Hard", whose R is 4.8 to 5.5 when hardness is Vickers 605 to 815.

Cast Steels – Cast steels are generally rather poor in their resistance to sand erosion, even when heat treated to high strength and hardness. R ranges from 1.2 for heat treated nickel steel (85,000 psi. ultimate) to 1.9 for cast Hadfield's manganese steel. It will be observed that austenitic manganese steel, the classical wear resistant material for parts which harden deeply under high impact, does not show especially high wear resistance against sand erosion. A Ni-Cr-Mo cast steel hardened to 175,000 psi. had R = 1.5. Cast stainless steels were slightly less resistant.

Wrought Steel – All rolled or forged steels had higher resistance than the standard low-carbon, annealed case hardening steel St C 16.61 (R = 1.00). A generalization is that the carbon and nickel-chromium alloy steels used for engineering purposes, when heat treated to tensile strengths no higher than 160,000 psi., will have resistance numbers of 1.2 to 1.5. The plain chromium steels, and chromium stainless steels, when heat treated to somewhat higher strength (225,000 to 270,000) have R between 1.7 and 2.2. Ball bearing steel (1% Cr, 1% C) of Rockwell C-61 to C-66 has much better resistance to sand erosion (R = 3.5). High speed toolsteel hardened to C-62 has R = 4.5, and a high-chromium, high-carbon steel hardened to Vickers 847 has a very high R = 6.0.

Surface treatments are quite various in their effects. As perhaps might be expected, sprayed coatings, electrolytic deposits of nickel, or siliconizing do not raise the erosion resistance of the standard appreciably above R = 1.0. However a deep nitrided case (surface hardness of Vickers 950) has R = 3.4, and the standard steel, carburized and quenched to surface hardness of C-68 has R = 4.0. Hard chromium plate is on a different level of resistance; R = 11.0 to 12.0.

Welded overlays have been widely used to reclaim badly eroded hydraulic equipment. The resistance of some representative materials to sand erosion varies over a wide range:

Hastelloy C	Vickers 283	R = 1.5
Stellite 12	Vickers 479	R = 2.4
High speed toolsteel	Vickers 772	R = 2.5
Stellite 12	Vickers 520	R = 3.4
Colmonoy 6	Rockwell C-52	R = 3.8
Tungsten carbide		R = 4.5
Stellite 1	Vickers 642	R = 4.6
Stellite 6	Rockwell C-43	R = 18.0

Sintered carbides used for tools and dies possess extraordinarily high resistance against sand erosion, as may be assumed from the sample shown in Fig. 5. Various European grades have been tested. Fifteen with Vickers diamond hardness numbers above 1225 had R = 16 to R = 92. The three with resistance numbers over 50 were Hartmetall HB (Vickers 1696), R = 63; Hartmetall G1 (Vickers 1270), R = 86; and Hartmetall H2 (Vickers 1809), R = 92. Norbide had a rating of R = 22.

Conclusion

The resistance numbers quoted above in extreme instances vary within a ratio of 1 to 500 or more. The wearing conditions in practice are, of course, not exactly the same and also vary within wide limits in different power stations as well as with different machines. However, the test results agree very well with conditions found in operating machinery, not only with respect to the order of rank but also quantitatively.

Heat Treatment of Steel for Good Machinability

*By H. OPITZ, S. AMMARELLER and H. KOELZER**

ALL METALLURGISTS and supervisors having to do with the cutting of metal know that its microstructural condition has an important influence on tool life, cutting speed, chip formation and surface finish. For important jobs, especially in large production, microstructure is either specified with the purchase order, or the material after receipt is given an appropriate heat treatment. Much of the information on such matters, held in the minds and records of various practitioners, is of a strictly empirical nature. However, the relationship between microstructure and heat treatment most favorable to tool life has occupied the investigator of machinability to an increasing extent.

Voluminous researches in this field in the last 25 years have produced numerous individual articles and summaries. (A bibliography of important items would reach at least 50 titles.) The few conclusions which may be drawn from this material, however, are neither complete nor general; contradictions also occur. Nevertheless, a critical review of all the published work produces a fairly uniform picture. Furthermore, inquiries among prominent German steel plants, drop forging plants and automobile factories confirm in essence the knowledge to be derived from the literature, and prove its outstanding practical significance.

Present German Practices

To give optimum machinability of plain carbon and chromium-manganese steels for case hardening, a structure consisting of ferrite and lamellar pearlite has proved itself uniquely favorable, especially in a uniformly coarse-grained condition. Since the chromium-nickel steels transform very slowly in the pearlite range, it is often simpler to heat treat them to a tensile strength favorable for chip formation.

In Germany, parts made of heat treatable steels (other than the carburizing grades) are most frequently machined after the complete heat treatment. The machining tolerances then are narrow. In the event that machining *precedes* heat treatment and a microstructure is required which machines easily, two objectives are possible – *(a)* the maximum possible chip production without special finish requirements or *(b)* a smooth surface. In the first instance a structure of ferrite and spheroidized cementite is preferable; the second instance is similar to conditions mentioned for the case hardening steels – namely, a ferrite-pearlite structure yields a good surface finish combined with satisfactory tool life.

For eutectoid steels, and even carbon steels with over 0.60% C (which essentially belong to the class of toolsteels) the pearlitic condition without pro-eutectoid ferrite is too hard for favorable machinability. Satisfactory tool life can then only be obtained when they are fully annealed.

Heat treatments will not be further discussed. Continuous cooling as well as isothermal transformation diagrams are now available for the steels commonly used in Germany, so a heat treatment corresponding to the specific require-

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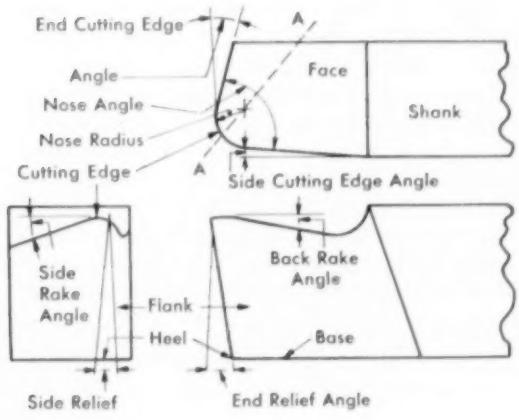
Machinability, as measured by cratering on the tool face when cutting a continuous chip, is directly related to shear strength. Suitable heat treatments minimize cratering and give a smooth surface finish. (G 17, J general)

ments and available equipment can readily be selected.

The investigations already mentioned have not revealed the *causes* of the difference observed in machinability, but this fact has not detracted from their practical significance. Efforts to relate all differences in machinability exclusively to the microstructural constituents, ferrite and cementite, have failed. Simultaneously with such changes, variations occur in other factors which are no less important to machinability, such as tensile strength, ductility, hardness, and toughness. However, it is amply proven that tool life is not directly proportional to any one or several of these mechanical properties. Only most recently, have we been able to establish a unique relationship between chip formation, tool wear and tool life, based on an inclusive study of tool wear – at least for the process of continuous chip formation without a built-up edge.†

Fig. 1 – Nomenclature of a Single Point Tool With Straight Shank, According to American Standards Assoc.



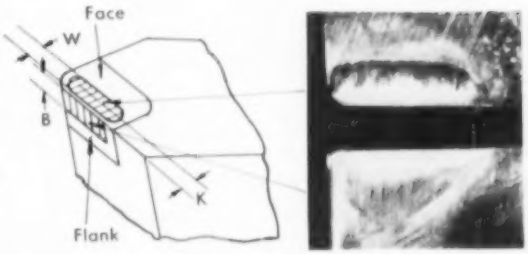


Fig. 2 – Hatched Areas Indicating Crater on Face and Wear on Flank of a Lathe Turning Tool

We will confine our attention in what follows to this particular problem and area in the broad field, and even here it will be impossible in small space even to mention some of the fundamental work which has been done in Germany and in other countries. Nomenclature will follow that recommended by the American Standards Assoc., as shown in Fig. 1.

Cratering

A comprehensive study of tool wear during continuous chip formation has been made by G. Weber and presented at the 1952, 1953 and 1954 conferences on machinability at Aachen. Wear occurs in many places, but for the above conditions, cratering on the face of the tool, as shown in Fig. 2, is of greatest importance. It increases the back-rake angle; its position and depth determine the end of the tool life and are largely inde-

† "Type 2 Chip", as shown in Fig. 3, p. 141, 1944 Supplement to A.S.M. Metals Handbook.

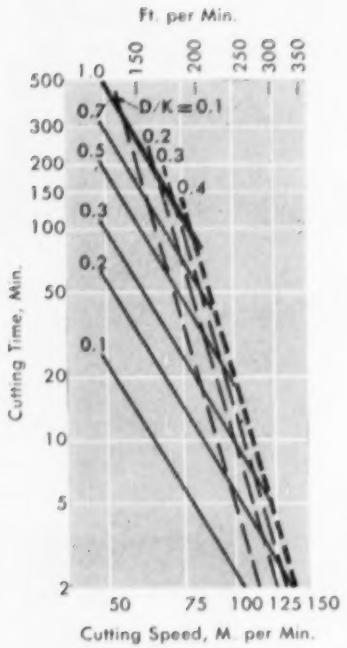


Fig. 3 – Weber's Diagram of Tool Life as It Depends on Cratering (D/K, With 0.4 as Limit) and Flank Wear (B, With 1.0 Mm. as Limit). Test log is plain carbon steel with 120,000-psi. tensile strength, cut with carbide tool ("Hart metall TT3" corresponding to U.S. Standard C 5), chip size 2.0 × 0.56 mm. (0.079 × 0.022 in.)

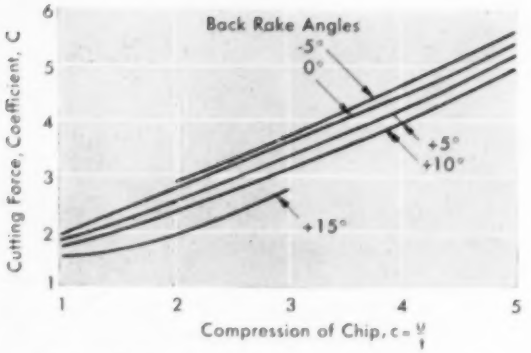


Fig. 4 – Relationship Between Cutting Force Coefficient C and Compression or Upset of Chip as It Varies With Back Rake Angle of the Tool

pendent of the width of the wear pattern. Its permissible width depends on economic considerations or on the required surface finish and dimensional tolerances – provided the tool itself is not endangered by the cratering.

Weber uses three parameters to define the wear: B is the width of the wear pattern on the flank (Fig. 2), W is width and D is the depth of the crater, and K is the distance from cutting edge to the center of the crater. His general conclusions are:

1. B versus cutting time T plots as a straight line on log-log paper, the slope of which is equal to or less than 45°.

2. D increases directly with T.

3. W increases with T, and the crater widens in both directions, toward and away from the cutting edge.

4. K does not change with time, but does depend on speed and feed.

5. Ratio between K and thickness of chip is constant for any given combination of workpiece and tool material.

6. Higher cutting speed and greater feed have a greater influence on cratering than they do on flank wear.

The dependence of B and D on T has been verified for sintered carbide tools (and also for high speed steel except for very high or very low cutting speeds).

Weber evaluates cratering by the ratio of its depth to its distance from the cutting edge (D/K). With continuous cuts and without chatter, the tool operates satisfactorily up to a condition where D/K = 0.4. He suggests that the complete wear conditions for variations in cutting speed and time may be plotted as in Fig. 3, a family of curves which apply to a definite combination of steel, cutting material and chip dimension. The heavy dashed line represents the end of tool life by cratering. Such data can be extrapolated but little for higher or lower speeds, because conditions are likely to change at extremes of speed, due either to a tendency of chips to weld onto the tool, or to wear at the nose, or to other phenomena.

Opitz and Weber have also found some general relationships between wear of carbide tools and generation of chips. The various forces arising during the formation of a continuous chip are directly proportional to the chip width. Assuming thin chips – at least five times as wide as they are thick – the data may be figured on the basis of a chip 1 mm. wide.

Analysis by Hucks* then shows that the main cutting force P as measured by a dynamometer is related to other factors by the equation $P = S \times w \times t \times C$, where S is the sheer strength along the inclined plane in front of the

*Presented at the Aachen conferences.

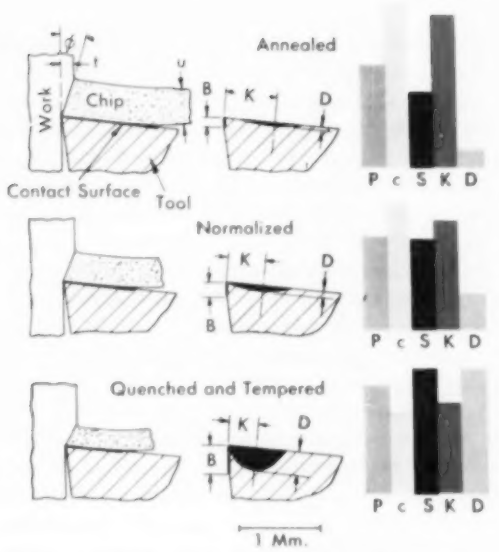


Fig. 5 – Variation in Cutting Conditions and Tool Wear on a Single Steel (Ck 60). Heat Treated to Three Different Structures. Sintered carbide tool L 3, depth of cut 0.0055 in., feed 0.008 in., speed 330 ft. per min., time=10 min. Crater depth is magnified five-fold in the sketch.

P = unit cutting force
c = compression of chip
S = shear strength

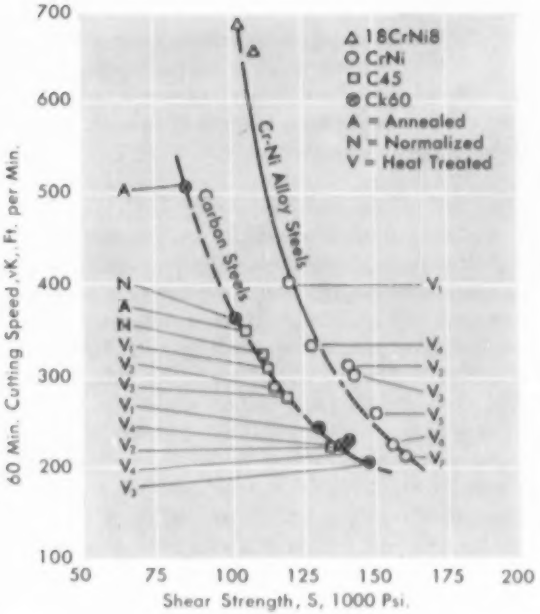


Fig. 6 – Cutting Speed vK to Produce a Crater Whose Depth is 0.1 K in 60 Min. Has Definite Relationship to Shear Strength in Heat Treated Carbon Steels, but Another Relationship Exists for Chromium-Nickel Steels. Cemented carbide tool of C 5 type

Steel	C	Mn	Si	Cr	Ni
18 CrNi 8	0.17	0.50	0.25	2.0	2.0
CrNi	0.35	0.70	0.35	1.0	2.7
C 45	0.45	0.65	0.25	–	–
Ck 60	0.60	0.65	0.25	–	–

tool, w is the chip width in mm., t is the theoretical thickness of the chips, and C is the cutting force coefficient – a function of the compression* as shown in Fig. 4.

The amount of upsetting which the chip endures, c, has wider influence than the main cutting force. Both the speed with which the chip rubs against the tool and the width of the contact surface depend on c, and mathematical relationships for these values are readily established. However it is probably better to illustrate the matter by Fig. 5, showing tests on plain carbon steel Ck 60 in three conditions: normalized to tensile strength of 110,000 psi., fully annealed to 85,000 psi., and hardened and tempered to 155,000 psi. Ck 60 has 0.57 to 0.65% C, 0.15 to 0.35% Si, 0.50 to 0.80% Mn, 0.035% max. P and 0.035% max. S.

The data illustrated are based on identical cutting conditions and cutting times. At the left is shown the chip compression. The wear profiles in the middle are magnified five-fold in depth. In the right-hand part of the figure, the chip generation is described through the main cutting force P for 1-mm. wide chip., the chip compression c and the shear S. The other two columns indicate the wear on the tool face. In spite of the considerable differences in the tensile strength of the steel in its three conditions, the cutting forces P are nearly alike. Wear is vastly different. Direct conclusions regarding tool life based on cutting force, therefore, are not realistic. The magnitude of the pressure on the contact surface and the rubbing speed, however, are important.

In the annealed condition with low shear strength, the chip upsets a great deal. This means a large frictional area on the tool, medium-low pressure and low rubbing speed. In the normalized steel and especially in the heat treated steel, the shear strengths are higher, while chip is not so thick and the contact area decreases. The average normal pressure and also the rubbing speed increase. The result is a deeper crater per unit time. Simultaneously, the edge of the crater reaches the cutting edge sooner. The temperature

*Compression c is the ratio of thickness of upset chip u to theoretical thickness of chip t; that is, $c = u \div t$

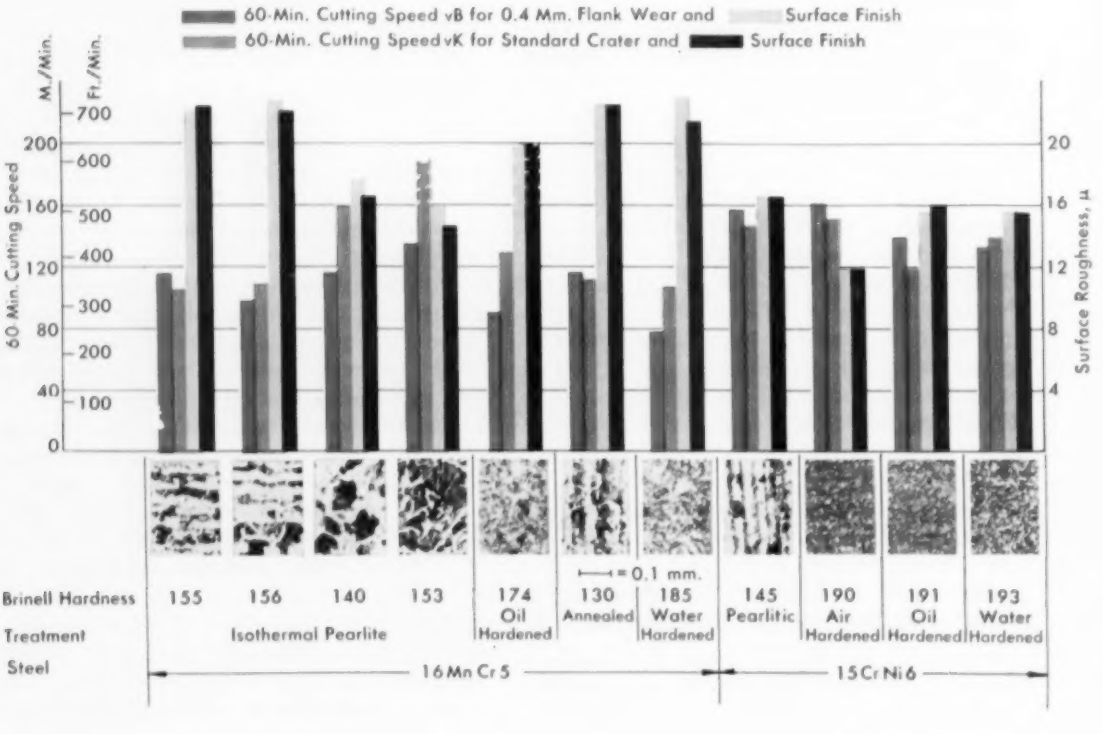
of the contact surface increases since the frictional temperature is at a maximum near the middle of the crater; this maximum approaches the cutting edge. This also results usually in increased wear on the flank.

Influence of Analysis and Microstructure

Numerous contributions in the literature have noted only minor differences in the cutting force when machining steels suitable for case hardening and full hardening. These results have been verified completely by work at the Technical College in Aachen under the author's direction. For example, five plain carbon steels with tensile strengths varying from 54,000 to 140,000 psi. were machined with identical toolings and the unit cutting force (figured on the basis of a chip 1 mm. wide) varied within the limits of 37 and 49 kg. (80 to 110 lb.). Similarly four alloy steels for case hardening varying between 65,000 and 115,000 psi. in tensile strength required unit cutting forces of 75 to 100 lb. Finally, four alloy steels for through hardening, 80,000 to 195,000 in tensile strength, required 88 to 112 lb. unit cutting force. In this whole range of steels from 65,000 to 195,000 psi. tensile strength, the maximum difference in cutting force amounted to only plus or minus 15%. Hence the following rule has been formulated:

With the most diverse structural steels after the most diverse heat treatments, the shear stress and the chip compression adjust themselves so that only minor differences occur in cutting force, which in no instance varies with the differences in tensile strength.

In further studies of two plain carbon steels C 45 and Ck 60 in annealed, normalized, and in four quenched and tempered conditions V_1 to V_4 of increasing tensile strengths, as well as two chromium-nickel constructional steels in several heat treated conditions, the wear on the tool after cutting a definite time, the cutting speed to reach limiting depth of the crater, as well as relations between chip dimensions or friction and the growth of the crater, were computed and plotted. The result agrees with the generally known fact that mechanical properties such as tensile strength, yield stress, elongation and impact toughness provide no unequivocal evidence concerning the tool life either with respect to cratering or tool flank wear. Heat treatments which lead to great differences in the tensile strength of the material may offer a basis for predicting the cratering action. Finer differentiations, how-



ever, cannot be made from the tensile strength.

More accurate predictions may be based on the shear strength. The above studies indicated that the tool life as determined by cratering decreases with increasing shearing stress in the shear plane. This really is to be expected, and it confirms the special influence of chip formation on machinability. In fact, all microstructural differences and concomitant differences in mechanical properties influence the chip formation. There are some relationships between mechanical properties and shear. Thus, for favorable machinability, the desirable heat treated structure should have low elongation in the tensile test and low notched-bar toughness without any increase in the tensile strength.

If the cutting speed vK to produce a crater whose depth is one-tenth of the distance to the center of the crater in 60 min. is plotted against the shear S for the four steels mentioned above, as in Fig. 6, the unalloyed and the Cr-Ni alloyed steels arrange themselves along separate curves. The form of the curves suggests an exponential relationship which would plot as a straight line on log-log coordinates. The two curves for 60-min. cutting speed prove that for identical rubbing conditions and shear stress, steels with different alloy combinations produce widely different wear.

Even though a definite relationship exists between cratering and chip generation, the amount of flank wear is much more obscure. Earlier investigations of the influence of microstructure on machinability were made along two lines—*(a)* observations of flank wear of sintered carbide tools, and *(b)* absolute breakdown of high-speed tools. This may be the reason for differences in opinion. According to the above discussions, one would expect flank wear to change simultaneously with cratering. We clearly find this tendency for the carbon steel, Ck 60, but for the Cr-Ni steel, an opposite behavior emerges. The lower toughness of the heat treated alloy steel has an especially favorable effect in reducing flank wear, but we have found that this effect is limited to light feeds. With heavy feeds, tool life decreases with flank wear as well as with cratering.

Microstructure and Machinability

Since there are so many influencing factors, machinability may be accurately evaluated only on the basis of extensive machining experiments. In practice, however, it is usually sufficient to

Fig. 7 (Opposite Page)—60-Min. Cutting Speeds and Resulting Surface Smoothness of Two Case Hardening Steels With Various Microstructures

Steel	C	Mn	Si	Cr	Ni
16 MnCr 5	0.15	1.15	0.25	1.0	—
15 CrNi 6	0.15	0.50	0.25	1.5	1.5

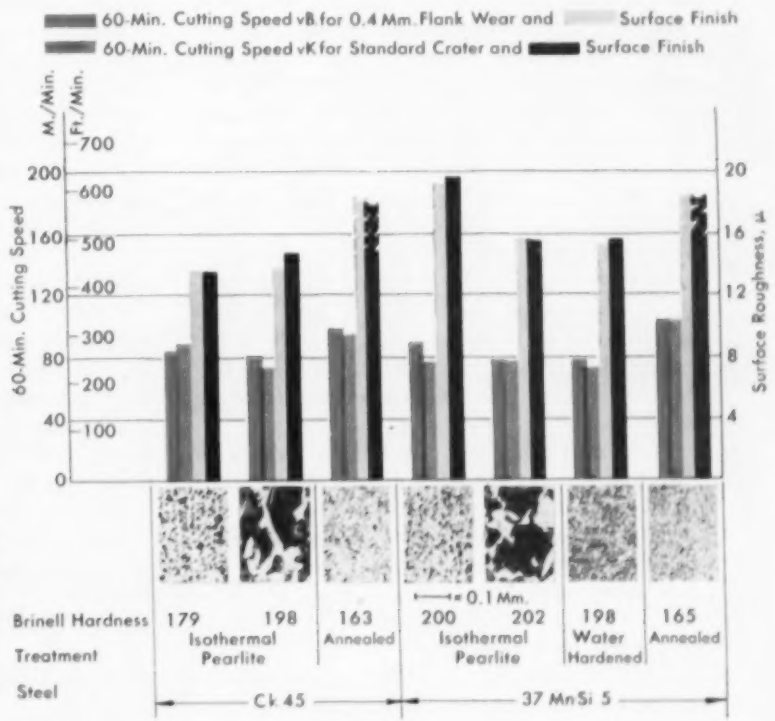


Fig. 8—60-Min. Cutting Speeds and Resulting Surface Smoothness of Two Heat Treatable Steels With Various Microstructures

Steel	C	Mn	Si
Ck 45	0.45	0.65	0.25
37 MnSi 5	0.37	1.25	1.25

test one or two quality characteristics – for example, tool life or obtainable surface finish. This can be done in a short time, and a careful check on production performance provides valuable supplementary information.

Examination of microstructure is a valuable shop auxiliary for estimating machinability, as a supplement to such mechanical tests as hardness, tensile strength, elongation and impact toughness. Microscopic examination readily checks a structure which experience shows is favorable.

Several series of microstructural standards are available, especially the Air Force report of work done by Curtiss-Wright. To supplement these with some of our relatively recent investigations, Fig. 7 and 8 are shown for two common German case hardening and two heat treating steels. Above each micrograph are bars showing the 60-min. cutting speed for a flank wear of 0.4 mm., for a crater whose depth is one-tenth the distance from edge of tool to center of crater, and the surface roughness for these two cutting speeds. The latter depend on the dimensions of the tool and chip. In the experiments the nose radius was 1 mm. (0.039 in.), and the feed was 0.25 mm. (0.010 in.) per revolution with a side cutting edge angle of 45°.

For the two case hardening steels, Fig. 7, the comparison between Brinell hardness and the two cutting speeds shows that hardness is no index for evaluating machinability. On the other hand, the micrographs show that when steel 16 MnCr 5, is in the pearlitic condition, the 60-min. cutting speed increases with increasing grain size and the surface roughness decreases. The coarse-grained annealed condition with Brinell of 153 gave the best surface finish and the cratering was so slight that the 60-min. cutting speed for this limitation could not be determined, even though speeds above 525 ft. per min. were used. The cutting speeds for this steel in heat treated conditions are low – comparable to the normal, fine-grained pearlitic condition with Brinell hardness of 155. This is also true of surface roughness.

With steel 15 CrNi 6, the best surface finish and tool life are obtained in the air hardened and tempered condition, Brinell 190. Similar tool life is also attainable in the pearlitic condition but the surface is rougher, partly because of the banded arrangement of ferrite and pearlite. Similarly, the pearlitic condition in steel 16 MnCr 5, at hardness levels of Brinell 155 and 156 has a banded microstructure and a fairly rough surface.

The heat treating steels both permit the highest 60-min. cutting speed in the soft annealed condition, but the surfaces were very rough. While grain size did not affect surface roughness very much for the unalloyed steel Ck 45 isothermally transformed to pearlite, tool life as measured by cratering was shorter as hardness and tensile strength increased. For 37 MnSi 5 alloy steel, grain coarsening did not change hardness and, correspondingly, the 60-min. cutting speed for cratering was even slightly increased over that in the fine-grained condition, and simultaneously the best surface finish was obtained.

Summary

A thorough study of tool wear on the flanks and tool face shows causal relationships between chip generation and tool life. Cratering is, we believe, the most important criterion for tool life when cutting continuous chips. Its position and depth determine the absolute limit of a tool's usefulness. In respect to cratering, a direct physical relationship between chip formation and tool life has been demonstrated.

All changes in the material's properties due to heat treatments influence the process of chip formation. The latter, therefore, can be summarized by a single measurement of the shear strength at the base of the chip. This quantity, therefore, is to be regarded as a quality index of machinability.

Another interesting conclusion is that the 60-min. cutting speed with respect to cratering changes exponentially with this shear strength, and the analysis of the steel determines the position and slope of the exponential curve.

When comparing the shear strength with tensile strength, hardness, elongation or notched-bar impact toughness, a number of indications may be drawn concerning the most suitable microstructural condition:

For Cr-Mn alloyed case hardening steels, these signposts point to ferrite-pearlite structures for improved tool life and surface finish, due to a uniformly coarsened grain size. For Cr-Ni alloyed case hardening steels, the air hardened and drawn condition is equal to the fine-grained ferrite-pearlite structure with respect to tool life – and even superior if a banded condition exists.

Heat treatable constructional steels machine with the longest tool lives in the soft annealed condition. However, the best surface finish is obtained from the ferrite-pearlite condition; a coarsened grain is also favorable provided the tensile strength or the hardness is not significantly increased.

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Personal Mention

Daniel J. Girardi ⊕ has been appointed to the post of metallurgical engineer in charge of research and process control at the Timken Roller Bearing Co., Canton, Ohio. Dr. Girardi will direct metallurgical research and mill metallurgical work for all divisions of Timken. A graduate of Wayne University, Dr. Girardi was granted a Ph.D. degree in metallurgy at the University of Michigan in 1941. After a brief career as a teacher at the University of Wisconsin, he became chief metallurgist of the Garfield Div. of Houdaille Corp. Starting with the Timken Roller Bearing Co. in 1946 as a research metallurgist, he became a research metallurgical engineer in 1952, which post he held until his recent promotion. Dr. Girardi is a past chairman of the Canton-Massillon Chapter of the Society, and a past chairman of the ⊕ Committee on Carburizing.

Herbert W. Graham ⊕, consultant to the president of Jones & Laughlin Steel Corp., Pittsburgh, was honored recently when the corporation's new research laboratory was dedicated as "The Graham Laboratory for J & L Research". Mr. Graham began his career with the corporation on his 23rd birthday in 1914, having just been graduated from Lehigh University with the degree of bachelor of science in electrometallurgy. With the exception of duty on loan to the Government during World War II, J & L has been his only employer.

Edward P. Sadowski ⊕ has joined the development and research division of the International Nickel Co., Inc., as a research metallurgist in the iron alloys section of the research laboratory at Bayonne, N. J. Following his graduation from the University of Notre Dame in 1950, with the degree of B.S. in metallurgy, Mr. Sadowski joined the M. W. Kellogg Co. as staff metallurgist, and prior to his association with International Nickel he served for two years on the staff of the eastern research laboratory of the Crucible Steel Co. of America.

Glen C. Riegel

Glen C. Riegel ⊕ has retired as chief metallurgist for Caterpillar Tractor Co., Peoria, Ill., where he has been employed since 1926. Mr. Riegel graduated from Central College, Fayette, Mo., in 1914, and after working two years in the chemical laboratory of the South Works of Illinois Steel Co., did graduate work at the University of Chicago. In 1918 he went with Mitchell Motors Co., Racine, Wis., and was promoted to chief metallurgist in 1923. He later moved to Milwaukee and took a position with the Gehrlinger Steel Casting Co., advancing from metallurgist to foundry manager in 1926. From here he went to Caterpillar Tractor Co. as production metallurgist.

With his retirement from Caterpillar, Mr. Riegel has accepted appointment as consulting metallurgist to the ⊕ Metals Handbook Committee. In this position he will work closely with a number of A.S.M. technical committees preparing articles for the next edition of the Metals Handbook.

In addition to numerous articles on induction heating and hardening, Mr. Riegel has a number of patents issued in this and other fields of engineering. He served on various war-industry committees, and has contributed to the Committee for Conservation of Strategic Alloys on the National Metallurgical Advisory Board. Mr. Riegel is an active member of many of the technical societies, before which he has presented papers, and also served various years on the handbook committees of the American Society for Testing Materials, Society of Automotive Engineers, American Welding Society, as well as the American Society for Metals. In 1946-47 he served as chairman of the S.A.E. Iron and Steel Technical Committee, in 1953 was vice-president for the Engineering Materials Activity, and in 1955 was named the S.A.E. Golden Anniversary author on engineering materials. Mr. Riegel was the first full-term chairman of the Peoria Chapter ⊕, of which he was co-founder, and served for many years on the executive committee of the Chapter.

Edgar C. Bain ⊕, vice-president, research and technology, United States Steel Corp., Pittsburgh, at the invitation of the Council of the University of Sheffield, England, recently delivered the Eighth Hatfield Memorial Lecture before the British Iron and Steel Institute. The subject of Dr. Bain's lecture was "Trends in Metallurgical Research in the United States".

Fred Heinzelman, Sr. ⊕ was given an honorary life membership at the last annual meeting of the Metal Treating Institute, in recognition of 22 years of continuous membership and his many contributions to the organization. At the same meeting the Annual Metal Treating Institute Achievement Award was presented to **L. L. McArthur** ⊕, chief metallurgist of Rollway Bearing Co., Inc., Syracuse, N. Y., and his co-author for their article on "Dimensional Control System Minimizes Finishing Costs". **Harold J. Babcock** ⊕, chief metallurgist of the Artillery Ammunition Div., Frankford Arsenal, delivered an address on "Heat Treatment of Steel Cartridge Cases".

R. Burns George ⊕, vice-president of sales, and **Lloyd D. Bowman** ⊕, vice-president of production for the Vanadium-Alloys Steel Co., Latrobe, Pa., were elevated to directorships at the recent annual meeting of the company.

N. E. Hamilton ⊕ is now engaged in consultant work in the vacuum metallurgy field.

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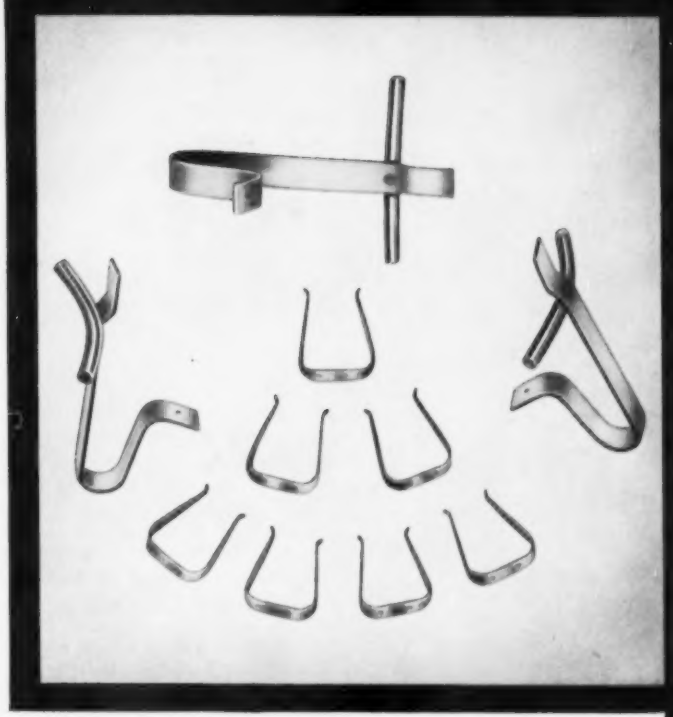
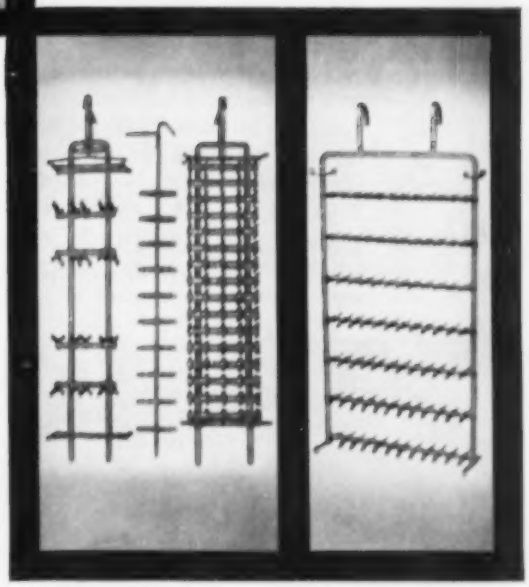


When small parts have to be plated, the problem arises as to how to hold them on the plating racks. If they are not heavy enough to hang by their own weight, spring clips must be used. For such clips, the Higgins Rack Coating Mfg. Co., Hazel Park, Mich., uses spring temper Revere Phosphor Bronze Strip. This material is specified because its spring temper gives it the ability to withstand repeated flexing, so that the clips can be used repeatedly, and that small parts can be snapped in and out of them quickly and without distortion.

The racks to which these clips are attached are made of copper bar; the clips are fastened by riveting and soldering. Everything except the contact points of the clips is coated to prevent deposition of the plating metal and loss of current. Higgins is an important supplier of these special racks to the automotive industry, which uses them to plate both interior and exterior trim. The efficiency and economy of this method helps make handsomer cars and trucks as well as numerous other attractive consumer commodities.

Clips and racks made to special designs by the Higgins Rack Coating Mfg. Co., which buys Revere Phosphor Bronze Strip for the clips from Copper and Brass Sales, Inc., a Revere Distributor in Detroit, Mich.



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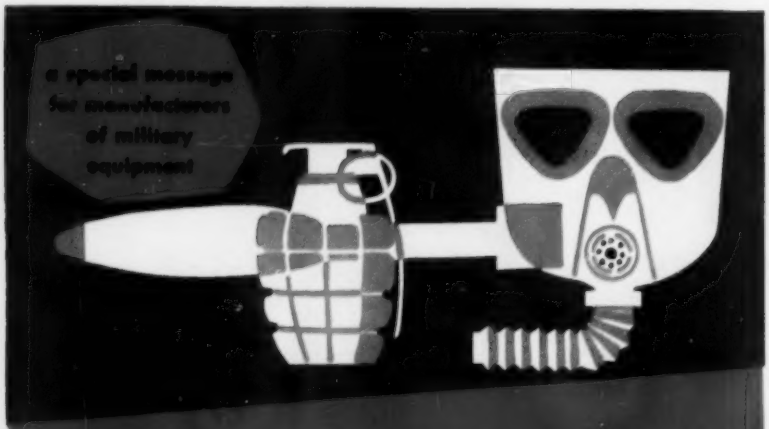

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AND IRIDITE IS EASY TO APPLY. Goes on at room temperature by dip, brush or spray. No electrolysis. No special equipment. No exhausts. No specially trained operators. Single dip for basic coatings. Double dip for dye colors. The protective Iridite coating is not a superimposed film, cannot flake, chip or peel.

WANT TO KNOW MORE? We'll gladly treat samples or send you complete data. Write direct or call in your Iridite Field Engineer. He's listed under "Plating Supplies" in your classified telephone book.

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Personals . . .

Eugene J. Kalil, who is registered to practice before the U.S. Patent Office specializing in metallurgical, chemical and mechanical patent matters, is now associated with Kolisch and Kolisch, New York.

Edward R. Stover was recently appointed research associate in the metallurgy and ceramics department of the General Electric Research Laboratory, Schenectady, N.Y., after having completed his work toward a D.Sc. degree at Massachusetts Institute of Technology. Following his graduation from M.I.T. in 1950, Dr. Stover served as a research teaching assistant and also held a G.E. fellowship for graduate study.

Jack J. Carlson has been appointed a vice-president of Kaiser Steel Corp. and general manager of the fabricating division plant at Montebello, Calif. Mr. Carlson joined Kaiser Steel in 1944 as administrative assistant. He was successively district sales manager in Seattle and Los Angeles, and was later appointed assistant general sales manager in the Oakland home office. In 1951 he was named general sales manager, and in 1954 became assistant to the vice-president and general manager.

Frederick P. Hesch is employed as production engineer for Aerojet-General Corp., Azusa, Calif.

Charles O. Smith is now a staff member of the Oak Ridge School of Reactor Technology, Oak Ridge National Laboratory, Oak Ridge, Tenn.

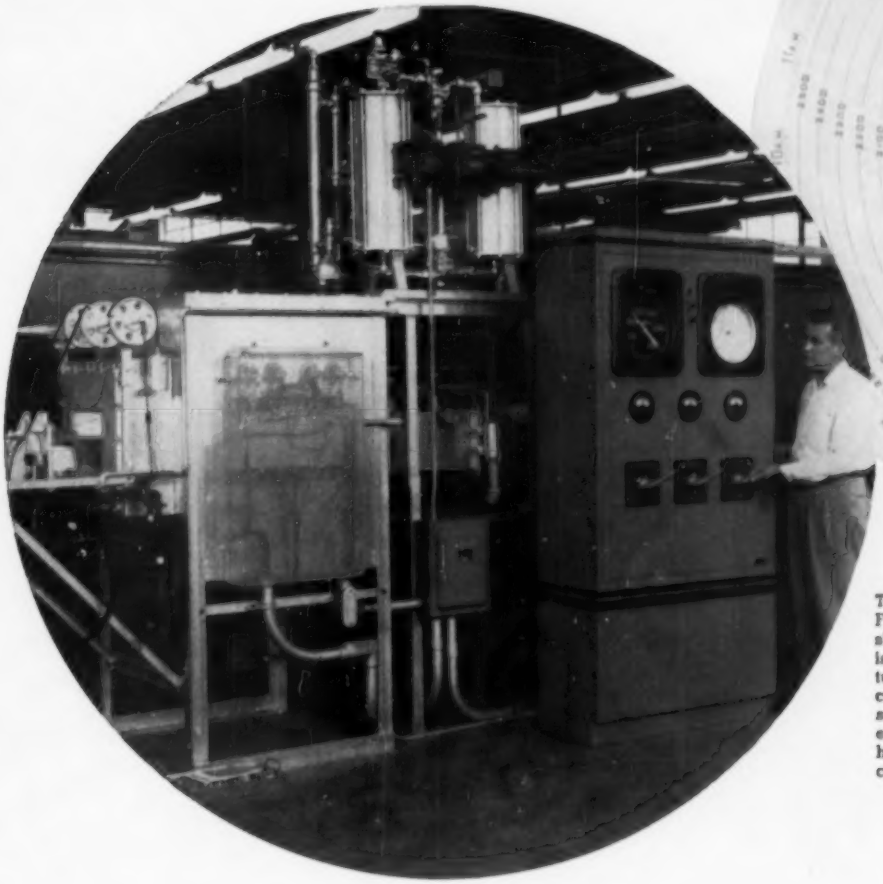
Max I. Beard has resigned as plant superintendent, gun carriage division, Oliver Corp., South Bend, Ind., to join Westinghouse Electric Corp. as a senior engineer in the LSR reactor department at Bettis Field, Pittsburgh.

Roger E. Crossweller, previously with Great Lakes Steel Corp., Detroit, is now in the technical service of wheel and brake development, Goodyear Aircraft Corp., Akron, Ohio.

David F. Dickinson is now acting head of the chemical engineering department at the University of Tulsa.

Furnace Temperatures "Toe the Line"!

. . . under new Foxboro Electric Proportional Control



This typical chart from Foxboro M/81b Controller shows how furnace (left) is brought up to temperature and precisely held at control point *without overshoot*. Installation is on electric furnace hardening high-precision, small machined parts.

Heat treating temperatures stay right on the control line when the new Foxboro M/81b Electric Proportional Controller handles furnace heat input. This fast-acting Controller assures the furnace a "balanced diet" of B.T.U.'s despite upsets, load changes, furnace lags, or ambient temperatures.

Control action is simple — effective. The M/81b senses any tendency of temperature to move away from pre-set control point . . . automatically varies ratio of heat "time-on" to "time-off" depending on changes in furnace loading. This *Proportional-set Average-position Controller* eliminates over- and under-shoot . . . maintains unusually uniform furnace conditions.

For top performance from your electrically heated or fuel-fired muffle-type furnace . . . new or modernized . . . investigate Foxboro Electric Proportional Control. Write for Bulletin 4-11.

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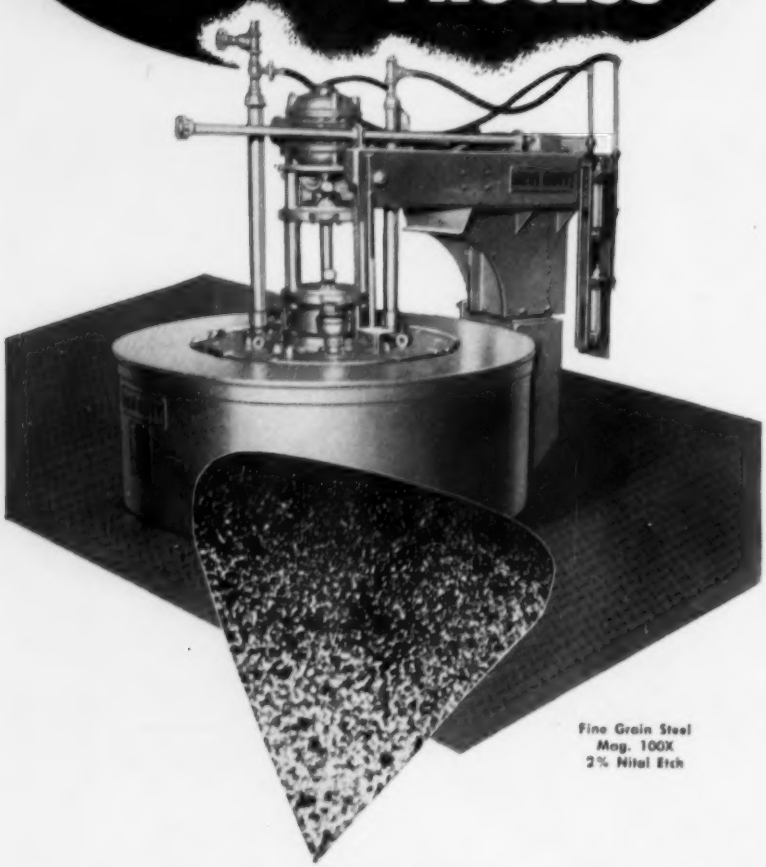
Electric
Proportional Controllers

FACTORIES IN THE UNITED STATES, CANADA, AND ENGLAND

CARBON CONTROL in the CARBURIZING PROCESS



Fine Grain Steel
Mag. 100X
2% Nital Etch

Time — Temperature — Carburizing Medium — Circulation — these have been accepted as essentials of the gas carburizing process. Now a 5th factor — **Pressure** — is established as being of primary importance. **POSITIVE PRESSURE CARBURIZING** has simplified the control of the amount and distribution of carbon in the case. Uniform results from heat to heat are realized — not only can the desired carbon concentration be obtained on the surface of the work but also to specified depths below the surface. Finish grinding may be performed without loss of uniformity of surface hardness — or may be eliminated entirely.

Hevi Duty Carburizer-Nitrider Furnaces are now equipped for controlled pressure carburizing. Inexpensive accessories can be provided to convert existing Hevi Duty Carburizers into controlled pressure carburizers to give you true carbon control.

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Chicago District
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HEAT TREATING FURNACES HEVI-DUTY ELECTRIC EXCLUSIVELY
DRY TYPE TRANSFORMERS — CONSTANT CURRENT REGULATORS

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Personals . . .

Don F. Atkins recently joined the staff of Kaiser Aluminum and Chemical Corp., Spokane, Wash., as a research metallurgist in the department of metallurgical research. Mr. Atkins was formerly employed at the Ames Laboratory of the Atomic Energy Commission, Iowa State College, Ames, Iowa.

Robert L. Heath was recently appointed head of materials and processes unit, propulsion center, North American Aviation, Inc., Los Angeles. Mr. Heath was for ten years manager of the Chicago district for Climax Molybdenum Co., and for 13 years prior to that was chief metallurgist, Allison Div., General Motors Corp., Indianapolis.

Richard J. Taglang, who graduated with a B.S. degree in metallurgy from the Pennsylvania State University in June 1955, has accepted a position as research assistant with Crucible Steel Co. of America, Pittsburgh.

Chauncey G. Newton, for the past 27 years district manager of the Rochester, N. Y., office of Pratt & Whitney Co., has resigned to manage a new sales engineering firm known as Anco, in the same city.

Donald P. Moon resigned as research metallurgist at Battelle Memorial Institute, Columbus, Ohio, to take a similar position in the Canton, Ohio, plant of United Engineering and Foundry Co.

Robert M. Goldhoff has completed graduate work leading to a Ph.D. degree in metallurgy at Ohio State University and is now employed in the materials and processes laboratory of the large steam turbine-generator department of General Electric Co., Schenectady.

Maurice E. Taylor is now working as research metallurgist for Rem-Cru Titanium, Inc., Midland, Pa., where he has been assigned to the manufacturing research group.

W. Bruce Clymer is now a metallurgist for Metallurgy, Inc., Newfield, N.J.

Tool Steel Topics

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Prompt service is your distributor's middle name. He makes it a point to know your city like a book—its background, its people, its industry. He knows what grades of steel you are most likely to need, and in what quantities. And so he keeps large stocks of Bethlehem tool steel on hand, in a virtually endless variety of types, all of them ready to go at a moment's notice.

If you would like bars cut to special length, or if there's a tricky phase of metallurgy or some other tool-steel problem troubling you—again, your distributor is at your beck and call. He's a real friend. They don't come any better. It will pay you to get to know him.

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ACCO products

Wilson "Tukon" Micro Hardness Testers

A model for every range of pyramid testing
Model LR—Floor model for Micro and Macro Hardness testing
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These "Tukon" models meet every fine test requirement

• WILSON "TUKON" Micro Hardness Testers are unexcelled for testing metallic and non-metallic parts such as fine wire, small precision parts, thin metal, shallow superficially hardened surfaces, jewels, plastics, glass, etc.

The three models pictured cover the entire range of diamond pyramid testing—with both Knoop and 136 degree Diamond Pyramid Indentors.

Proper selection of the proper model for your particular requirement depends on the type and thickness of work to be tested, range of loads, purposes for which the machine is to be used—research or control, other hardness testing equipment available and whether a combination of micro and macro hardness testing is required.

We invite you to consult with WILSON engineers on your hardness testing problem. There is no obligation. Write for **Booklet DN-114** *on WILSON "TUKON" Micro Hardness Testers.*

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AMERICAN CHAIN & CABLE
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WILSON "ROCKWELL" and "TUKON" Hardness Testers

Personals . . .

H. Charles Yaeger has been appointed manager of manufacturing at Pesco Products Div. of Borg-Warner Corp. in Bedford, Ohio. He previously was factory manager of Jacobs Aircraft Engine Co., Pottstown, Pa.

Charles F. Sawyer has been appointed works manager of the Latrobe mill, Vanadium-Alloys Steel Co., Latrobe, Pa., after serving nine years as plant metallurgist.

John W. Price, Jr. has been appointed assistant general superintendent of the Duquesne works of United States Steel Corp. Mr. Price is a 1937 graduate of Case Institute of Technology and began his service with U. S. Steel at the Homestead plant as a metallurgical observer. He became assistant chief metallurgist in 1942. In 1945, he went to the Pittsburgh offices as bureau manager of the railroad material metallurgical division. Mr. Price returned to Homestead in 1950 as assistant to the general superintendent, and in July 1954 was appointed superintendent of the slabbing and plate division.

Charles B. Buker has been promoted from Detroit district metallurgical engineer for Jones & Laughlin Steel Corp., to supervisor of technical services in the general offices in Pittsburgh.

Stanford O. Smith, formerly with Fort Pitt Steel Castings Div., Pittsburgh Steel Foundry Corp., McKeesport, Pa., resigned to accept the position of steel foundry metallurgist at Texas Foundries, Inc., Lufkin, Tex.

Willard M. Garcia, metallurgist at Kawneer Co., Niles, Mich., has resigned to join the Oliver Corp., South Bend, Ind., in the same capacity.

Rudolf H. Thielemann, formerly development metallurgist at Pratt and Whitney Aircraft, East Hartford, Conn., is now associated with the Stanford Research Institute, Menlo Park, Calif., where he plans to continue working in the field of high-temperature materials and is manager of the metallurgical section of the Institute.

NOW *Preformed* crucibles, boats, funnels

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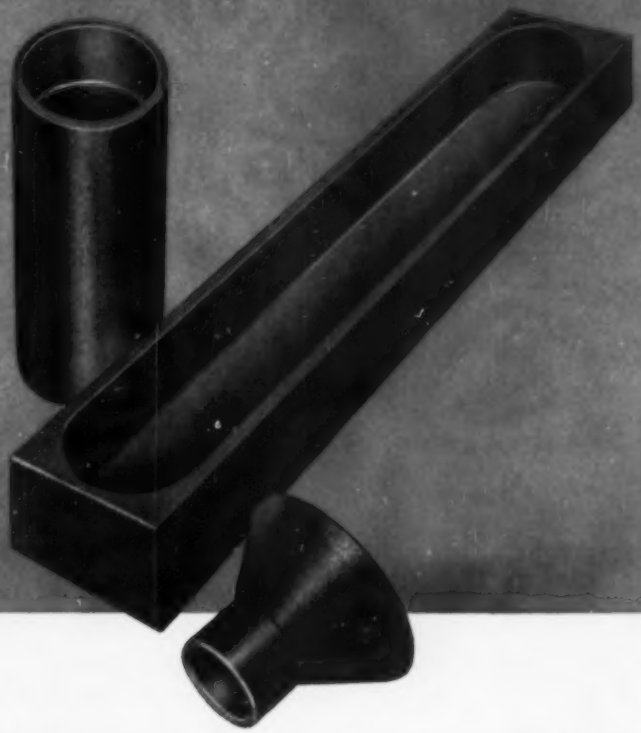

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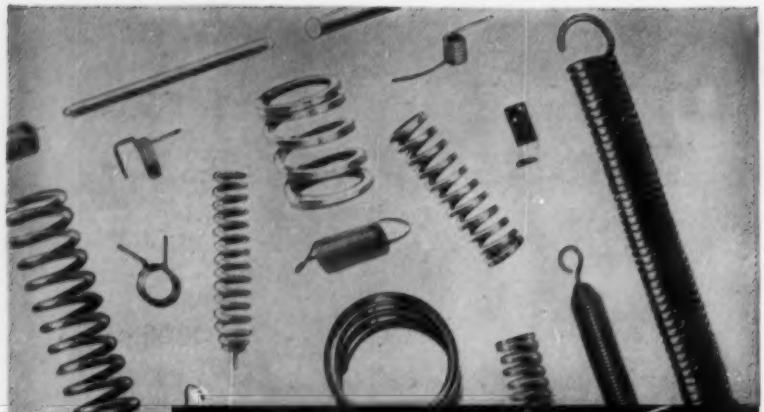

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Prospect Park, Pennsylvania

Personals . . .

George Bennett, general manager, was recently elected president of the Borroughs Mfg. Co., Kalamazoo, Mich. Before joining Borroughs in January 1955, Mr. Bennett was assistant to the vice-president in charge of production at American Metal Products Co., Detroit.

Edward N. Case has been appointed sales manager of the Ajax Electric Co., Philadelphia, after 12 years with the American Cyanamid Co., New York, as manager of the metal chemicals section. Mr. Case is a graduate of Union College, and took post-graduate work in metallurgy and chemistry at Brooklyn Polytechnic Institute. He has been granted several patents, contributed articles to a number of technical journals including *Metal Progress*, and has been in demand as a lecturer before the various societies.

Raymond Meyer, administrative assistant to the vice-president, has been appointed supervisor of manufacturing for ElectroData Corp., Pasadena, Calif. Mr. Meyer is a graduate of the University of Denver, with advanced study at Harvard University and Massachusetts Institute of Technology.

Norbert L. Kopchinski, now manufacturing engineer, nuclear research and development, for the Glenn L. Martin Co., Baltimore, Md., was formerly welding engineer with Grumman Aircraft Engineering Corp., Bethpage, N. Y.

Michael J. Savitski has resigned as associate professor of mechanical engineering at the University of Dayton and is now a magnetic materials engineer in the materials engineering department at Westinghouse Electric Corp., East Pittsburgh, Pa.

R. O. Hutchison, formerly director of nuclear engineering for Lockheed Aircraft Corp., Marietta, Ga., has accepted a position as technical assistant to plant manager, atomic energy division, Babcock & Wilcox Co., Lynchburg, Va.

Arnold D. Arnaut was recently promoted to district manager of the Linden, N. J., sales office of Wall Colmonoy Corp.

6 OUT OF 10 ARE GRANODIZED

Six out of 10 cars in this lot at Standard Pressed Steel, Jenkintown, Penna., are Granodized with Granodine® before painting. Why do most automobile manufacturers use this crystalline zinc phosphate undercoating? The reasons are simple. Granodine provides a lasting bond between paint and steel. It forms an inert barrier against rust. It assures a fine and durable paint finish.

Automobile manufacturers depend upon Granodizing with Granodine, too, because of the technical assistance offered by ACP. Not only do we supply the chemicals — we also put them to work and, what's more, keep them working effectively.

Your sheet steel products also can have these extra sales features. Investigate the advantages of Granodizing with Granodine. Contact your nearest ACP sales office or write us.

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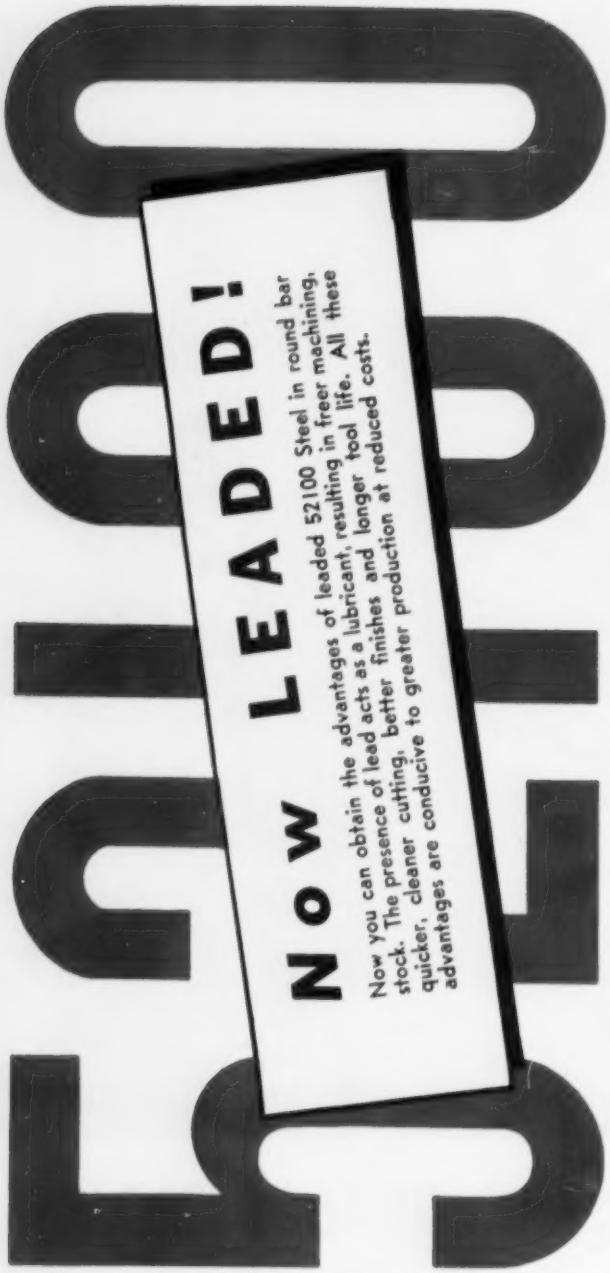
DETROIT, MICHIGAN NILES, CALIFORNIA WINDSOR, ONTARIO

CHEMICALS ACP PROCESSES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NOW
Now you can obtain the advantages of leaded 52100 Steel in round bar stock. The presence of lead acts as a lubricant, resulting in freer machining, quicker, cleaner cutting, better finishes and longer tool life. All these advantages are conducive to greater production at reduced costs.

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DEPT. 1

55-8

PETERSON STEELS, INC.
UNION, NEW JERSEY
Detroit, Michigan • Chicago, Illinois

Personals . . .

Walter J. Albright ⊖, formerly with James B. Clow & Son, Coshocton, Ohio, is now melting and cleaning room foreman with Brown Industries, Inc., Sandusky, Ohio.

Alexander Zekany ⊖ has resigned as research engineer with North American Aviation, Inc., and is a metallurgist with Denison Engineering Co., Columbus, Ohio.

Eric B. T. Kindquist ⊖ is now president of Everite Co., Inc., New York City.

Norman S. Eddy ⊖ has resigned as research engineer with Battelle Memorial Institute, Columbus, Ohio, to accept a position as metallurgist with Wyman-Gordon Co., Worcester, Mass.

Norman J. Hagen ⊖ has been transferred by Wilkinson Co., Ltd., from Edmonton, where he was a salesman, to Calgary, Alberta, as district sales representative in charge of the new sales office.

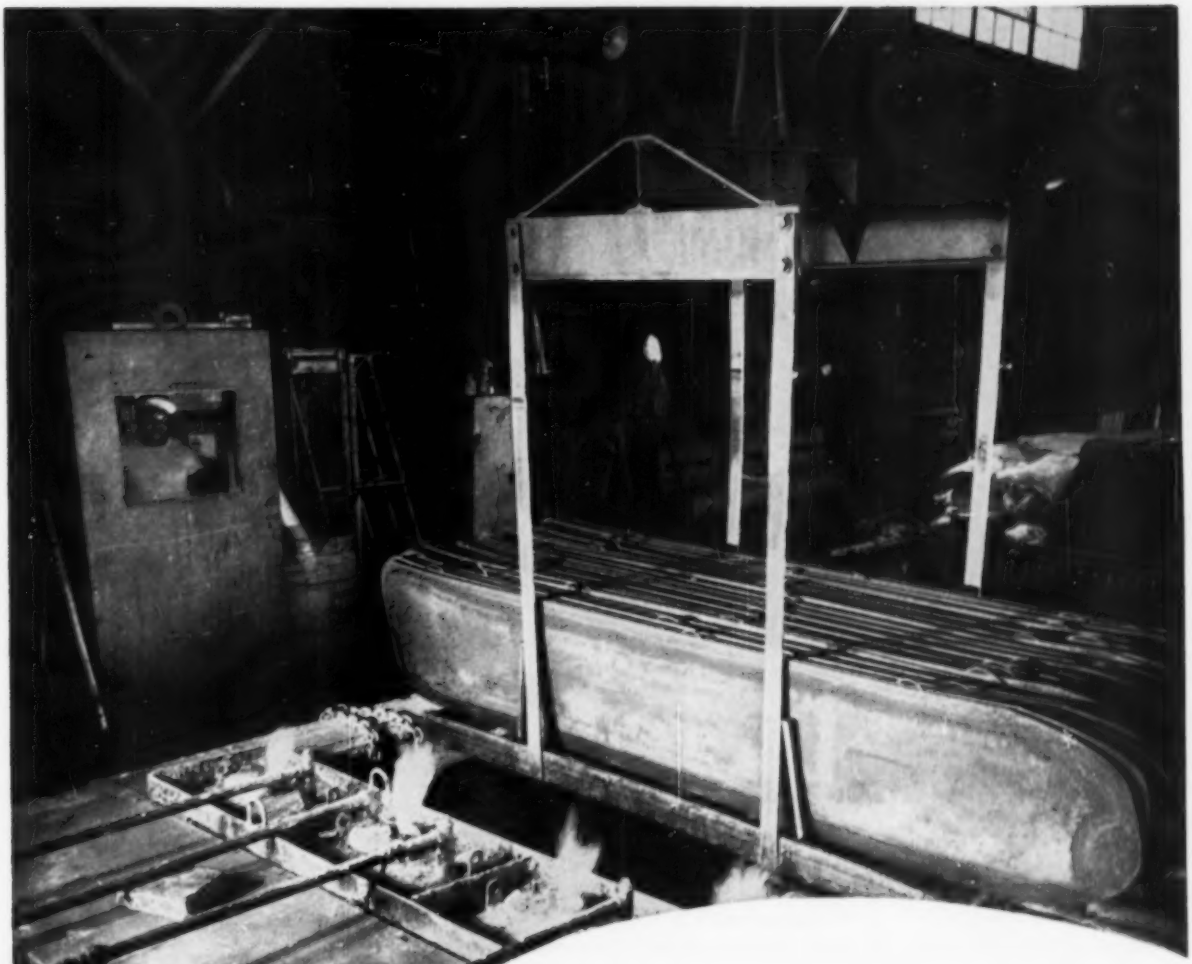
Raymond J. Thomas ⊖, formerly ordnance metallurgist at Raritan Arsenal, Metuchen, N. J., and past chairman of Lehigh Valley Chapter ⊖, is now senior experimental metallurgist, Allison Div., General Motors Corp., Indianapolis, Ind.

Edward C. Bishop ⊖ is now manager, wrought alloy engineering, materials manufacturing department, Westinghouse Electric Corp., Blairsville, Pa.

S. Fillingham ⊖, formerly master mechanic at the Rock Island, Ill., works of J. I. Case Co., is now connected with Home-O-Nize and Prime Mover Co., Muscatine, Iowa.

William Pollack ⊖ has joined the staff of Armour Research Foundation of Illinois Institute of Technology as associate metallurgist in the powder metallurgy section of the metals research department.

Anthony Del Grosso ⊖, previously employed as heat treat metallurgist at Burroughs Corp., Detroit, is now metallurgist for Atomic Power Development Assoc., Inc., in the same city.



Safely descale most metals in 20 minutes or less!

WITH THE DU PONT SODIUM HYDRIDE PROCESS

You can thoroughly descale any metal unaffected by fused caustic at 700°F.—in any size or shape—within 20 minutes in a sodium hydride bath. And because bath action stops the instant scale is reduced, there's no loss of valuable base metal—no pitting or etching to cause costly rejects.

Du Pont—pioneer of sodium hydride descaling—will be glad to give you all the details about its economical, easy-to-operate process. Just write or phone Du Pont's nearest district office or mail the coupon below.

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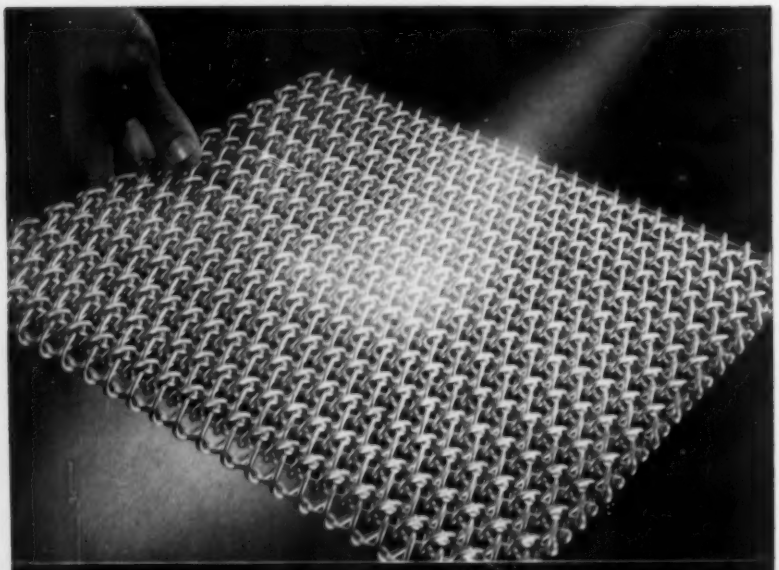

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means continuous low-cost heat treating with *Cambridge* WOVEN WIRE CONVEYOR BELTS

Open mesh construction lets heat and gases circulate freely all around the work for uniform annealing, brazing, sintering at controlled rates of speed. Moving belt eliminates batch handling, cuts costs, provides continuous production.

All-metal Cambridge Woven Wire Conveyor Belts are impervious to damage from constant operation at temperatures up to 2100° F . . . have no seams, lacers or fasteners to wear more rapidly than the body of the belt, no localized weakening. Open mesh also permits free drainage of process solutions in quenching, pickling and tempering.

No matter how you look at it, CAMBRIDGE Woven Wire Conveyor Belts are invaluable aids to AUTOMATION . . . eliminate profit-stealing batch and hand operations. They are made in any size, mesh or weave, and from any metal or alloy. Special raised edges or cross-mounted flights to hold your product during movement are available.

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WRITE TODAY FOR FREE 130-PAGE REFERENCE MANUAL illustrating and describing woven wire conveyor belts. Gives mesh specifications, design information and metallurgical data.

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OFFICES IN PRINCIPAL INDUSTRIAL CITIES

Personals . . .

P. A. Haythorne, previously division chief engineer for P. R. Mallory & Co., Indianapolis, Ind., has joined Rheem Mfg. Co., Downey, Calif., as chief engineer in the aircraft division.

Edgar L. Von Rosenberg was recently named chief metallurgist for American Iron & Machine Works, Oklahoma City, Okla.

T. V. Philip, after completing the requirements for the degree of Ph.D. in metallurgical engineering at University of Wisconsin, has joined the staff of the department of mining and metallurgical engineering at the University of Illinois as a research associate.

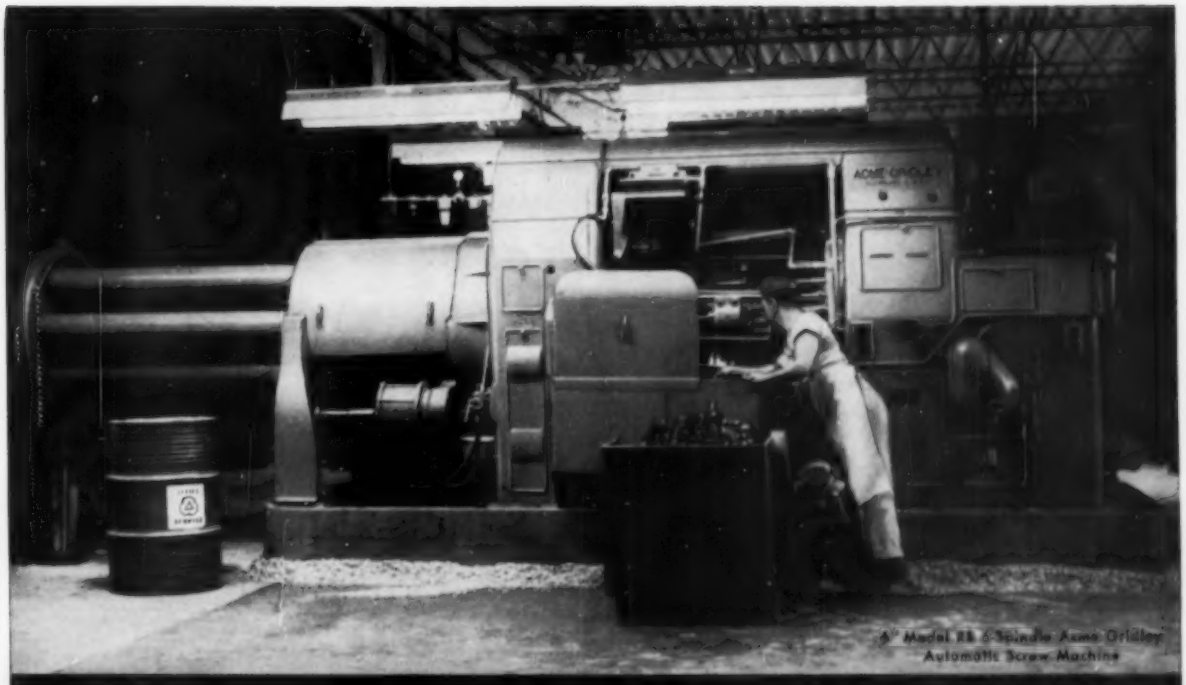
Henry J. Fischbeck, after 40 years in the metallurgy and chemical processing of aircraft engine materials, has retired from Pratt & Whitney Aircraft, East Hartford, Conn., as staff metallurgist of advance tool engineering.

Robert C. Perfall is on leave of absence from AiResearch Mfg. Co., Los Angeles, to work toward a master's degree in mechanical engineering at the California Institute of Technology.

Ab Flowers, formerly in the metallurgical division of Combustion Engineering, Inc., Chattanooga, Tenn., where he was past chairman of the Chattanooga Chapter, recently joined Rem-Cru Titanium, Inc., Midland, Pa., as research metallurgist in the manufacturing research division.

Donald L. Dyke has been transferred as metallurgist from Hotpoint Co., Div. of General Electric Co., Milwaukee, Wis., to the manufacturing engineering department of General Electric's general purpose control department at Bloomington, Ill.

Joseph W. Drosdick was the recipient of an award in the structural division of the James F. Lincoln Design for Arc Welding Contest. Mr. Drosdick received his B. S. degree in metallurgical engineering in 1955 from Lafayette College, and is a methods department trainee at Rome Mfg. Co. Div., Revere Copper & Brass, Inc., Rome, N. Y.



6" Model RB 6-Spindle Acme Gridley Automatic Screw Machine

ONLY 5 MORE LIKE IT IN THE WORLD!

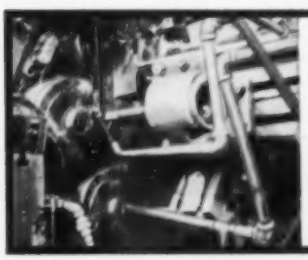
Owned by Jessen Manufacturing Company, today's most advanced automatic screw machine uses Cities Service Cutting and Hydraulic Oil

Weighing 39 tons and powered by a 60 H.P. motor, this 6-inch, 6-spindle Acme Gridley Automatic Screw Machine is one of the only six now in existence . . . and the only one owned by a job shop. Featuring a combination pneumatic-hydraulic operation, it can turn out a single load of stock weighing 3 tons!

The owner is Jessen Manufacturing Company of Elkhart, Indiana—since 1923 famous for keeping on top of new developments. It's not strange, therefore, that for this advanced new machine they chose a top quality coolant—a Cities Service cutting fluid.

Says President J. H. Jessen: "We're happy to say that the Cities Service cutting oil we use today is one of the finest all-around cutting oils we have ever used. In years past, we felt that if a cutting oil was good, it had to be black, heavy, and odorous. Cities Service has changed our minds with a cutting oil that has outstanding cooling abilities, good chip drain-off, is anti-weld . . . and yet possesses light, clear color and has no noticeable odor. In addition, Cities Service Pacemaker Oil used in hydraulic systems, and Amplex Lubricating Oil are doing an outstanding job throughout our shop. We proudly recommend *all* these Cities Service Oils."

For more information on the complete line of Cities Service cutting fluids, call in a Cities Service Lubrication Engineer. Or write: Cities Service Oil Company, Sixty Wall Tower, New York 5, N. Y.



Light, Clear Coolant in Acme-Gridley Automatic is Cities Service cutting oil. "Outstanding cooling, anti-weld, and chip drain-off ability," says Jessen. Firm also praises Pacemaker Oils, used in their hydraulic operations.

Jessen Mfg. Company, Inc. Mr. Jacob Jessen, Pres., in business since 1923, has earned reputation of keeping on top of new developments. In 1935, he was one of the first to install 6-spindle, anti-friction bearing screw machine.

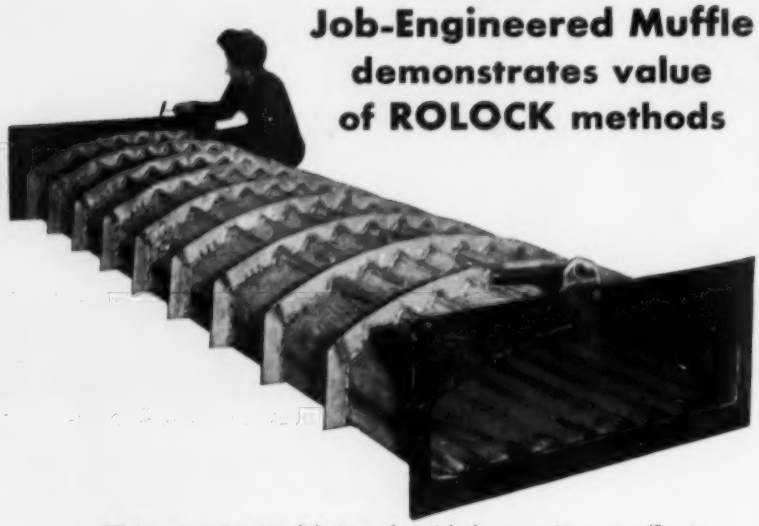
CITIES SERVICE

QUALITY PETROLEUM PRODUCTS

ROLOCK

FABRICATED HEAT AND CORROSION RESISTANT ALLOYS

2700-lb. Job-Engineered Muffle demonstrates value of ROLOCK methods



This completely fabricated-welded annealing muffle is 13'10" long, 14" high inside, and 48" wide. The material is 5/16" Inconel. It is used for continuous annealing of copper and brass tubes at 1600°F. in a Rockwell muffle furnace.

The use of homogeneous wrought alloy in an integrated pattern of ribs and corrugations permits relatively thin metal sections for rapid heat recovery and close temperature control with structural strength at tempertaure.

Equipment engineered to the job in close cooperation with the customer and fabricated to Rolock's high quality standards is setting new standards of performance in the heat treating field.

This is just one example from our current production. If you use muffles, furnace retorts, furnace trays or other heat and/or corrosion-resistant equipment, you should know about the services Rolock offers. Write now for our NEW Catalog No. G-10, most comprehensive publication of its kind available.

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Easier Operation, Lower Cost

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Personals . . .

Richard H. Haupt, plant metallurgist and sales engineer at Federated Metals Div., American Smelting and Refining Co., Whiting, Ind., recently resigned to join the Glenn L. Martin Co., Baltimore, Md., as a research metallurgist.

William Gowder, metallurgist at Universal Cyclops Steel Corp., Titusville, Pa., has been transferred to the New York office.

James B. Russell recently resigned as research metallurgist, department of metallurgical research, Kaiser Aluminum & Chemical Corp., Spokane, Wash., to accept a position as development engineer, Nichols Wire & Aluminum Co., Davenport, Iowa.

S. Mocarski has joined the industrial engineering department of the Ford Motor Co. of Canada, Ltd., Windsor, Ont., as a production engineer.

B. J. Bastian, former research associate at Rensselaer Polytechnic Institute, is now metallurgist at Thomas A. Edison, Inc., West Orange, N. J.

Sidney B. Klein was recently appointed acting head of the design department of Fairchild Controls Corp., New York.

Sheng-Tai Shih, who obtained his Ph.D. degree in metallurgical engineering from the University of Missouri School of Mines and Metallurgy in 1954, served as research metallurgist at the same school until September 1955, when he resigned to join the staff at Montana School of Mines as assistant professor of metallurgical engineering.

Lee E. Tanner has terminated his service with the U. S. Army and is now a student in the School of Metallurgical Engineering at the University of Pennsylvania, where he is working toward an M.S. degree in metallurgical engineering.

H. P. Leighly, Jr. is now a research metallurgist at Denver Research Institute, University of Denver, Colo.

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Personals . . .

Vernon Griffiths, who graduated from Massachusetts Institute of Technology, department of metallurgy, with a degree of Sc.D. in September 1955, is now engaged in powder metallurgy research for Sherritt Gordon Mines, Ltd., Fort Saskatchewan, Canada, at the department of mining and metallurgy, University of British Columbia. Dr. Griffiiths is also an instructor on a part-time basis.

John T. Ballass, having completed work at the graduate school of metallurgy at Lehigh University, is now employed at the Electric Boat Div., of General Dynamics Corp., Groton, Conn.

William G. Neal, who graduated in May 1955 from the University of Detroit with a bachelor's degree in chemical engineering with metallurgical option, is now on the training program at the Copper Cliff, Ont., smelter of International Nickel Co. of Canada, Ltd.

Ernest F. Nippes, director of welding research at Rensselaer Polytechnic Institute, has begun a new program of research for the Westinghouse Electric Corp., Pittsburgh. Dr. Nippes and associates in the division of research are to conduct ductility tests on high-temperature alloys furnished by Westinghouse with the primary purpose of evaluating the reaction of these materials to welding processes.

James F. Watson, after being discharged from the U. S. Army where he was assigned to the Ballistic Research Laboratory, Aberdeen Proving Ground, Md., has returned to the University of Michigan to do graduate work in metallurgical engineering.

Frank D. Haskins has retired after 27 years as an instructor at General Motors Institute, Flint, Mich.

Thomas L. Joseph, Jr., recently separated from the U. S. Army, is now employed as technical service engineer in the industrial tape division of Minnesota Mining & Mfg. Co., St. Paul, Minn.

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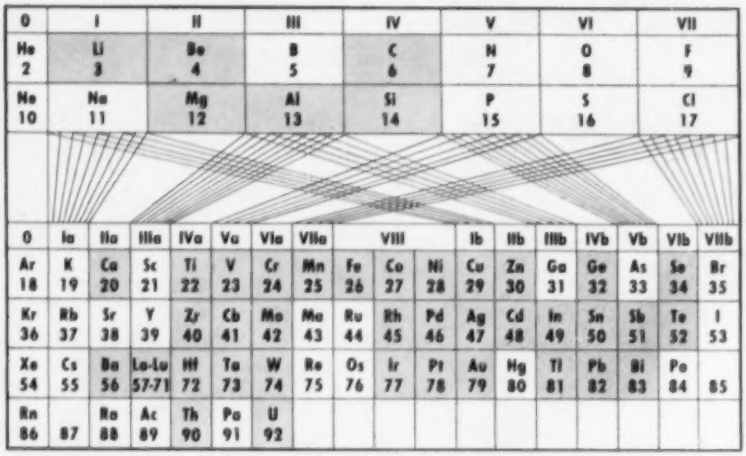
Digests of Important Articles . . .

Selection of Bearing Metals

Digest of "Why Bearings Seize", by Arvid E. Roach and Carl L. Goodzeit, *General Motors Engineering Journal*, Vol. 2, Sept.-Oct. 1955, p. 25-29.

FORTY metallic elements were studied as slider bearings in contact with steel and the results have shown that bearing properties depend upon atomic properties. Briefly stated, a good combination of bearing metals will have atomic sizes so different that few junctions are formed between them when rubbed together; and further, the metals should be in the b-subgroups of the periodic system of the elements, as shown in the sketch alongside.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Ar 18 K 19 Ca 20 Sc 21 Ti 22 V 23 Cr 24 Mn 25 Fe 26 Co 27 Ni 28 Cu 29 Zn 30 Ga 31 Ge 32 As 33 Se 34 Br 35
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40 Elements Tested as Slider Bearings Against Steel Are Indicated by Shaded Portions in the Periodic Table. Elements which make good bearings are found in the b-subgroup

Of the 40 elements tested, ranging from lithium (atomic number 3) to uranium (atomic number 92), only nine are rated "good" in sliding contact with steel. They are germanium, silver, cadmium, indium, tin, antimony, thallium, lead and bismuth. Relative ratings were not affected by the choice of lubricant.

Whether two metals will slide smoothly upon each other or seize violently (weld) appears to depend upon two factors – how many atoms on the surface of one body match up with corresponding atoms on the surface of the other body; and how strongly these atomic junctions adhere. If adhesion is to be minimized, metals should be chosen whose crystal lattices are so different there will be poor matching between atoms on contacting surfaces – in other words, metals whose atoms differ greatly in size. Good bearing metals usually are those whose atomic diameters are at least 15% greater than that of the iron atom (2.48 Angstrom units).

Exceptions are lithium, magnesium, calcium and barium, which are poor bearing metals even though their atomic diameters are large; and germanium and tin, whose atomic diameters are close to that of iron but do have good bearing properties. The reason is related to the second factor, position in the periodic table, which gives a rough indication of the type of atomic junction that will be formed between metals.

Two principal kinds of bonds may be formed between metals. The first and more important is the metallic bond resulting from the attraction between positively charged metal cations and their associated negatively charged valence electrons. Valence electrons are free to move about in the interstices between the cations and it is this mobility which makes metals good conductors of electricity and heat. The metallic bond is tenacious and when pulled will give but not let go.

The second type of bond arises from the sharing of valence electrons between adjacent atoms in such a way that each of the participating atoms, in effect, completes its valence shell. The resulting "covalent" bond is stable, relatively rigid and unyielding, leading to brittleness.

If two metals form wholly metallic junctions, they will be poor bearing materials even though the number of atomic junctions may be small. If junctions are partly covalent, bearing properties will be better. If the junctions are entirely covalent the metals will perform extremely well as bearings. Metals in the b-subgroups of the periodic table form junctions in which metallic and covalent binding are mixed, thereby rating high in bearing properties.

As mentioned, germanium and tin are metals with atomic diameters close to that of iron, yet they rate good in bearing tests. The explanation lies in the fact that they react with iron to form intermetallic compounds of definte stoichiometric composition with covalent binding. Resulting junctions are so brittle and easily broken that it does not matter whether there are many or few.

The two conditions of favorable atomic size and favorable position in the periodic table – keeping in mind the proviso concerning intermetallic compounds – together constitute a complete theory of bearing metals to which there are no known exceptions.

Practically speaking, only a few metals are used as bearings. These are silver, lead, tin and, to a lesser extent, indium and calcium. With the possible exception of silver, they are all weak and must be used in thin layers reinforced by a strong backing to prevent extruding under load.

A number of commercial bearing materials comprise metals having relatively low solid solubility, such as copper-lead, aluminum-tin and aluminum-cadmium. Such materials represent efforts to combine the superior bearing properties of lead, tin and cadmium with the superior

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Bearing Metals . . .

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Of the various alloys used as bearing metals, many are simple solutions of two or more good bearing metals, such as lead-tin and lead-indium. While alloying two good metals does not harm their bearing characteristics, neither does it improve them. The object of alloying usually is to improve corrosion resistance, castability or some other property.

Babbitt, one of the most important commercial bearing metals, is an alloy consisting of a two-phase material made up of hard particles in a soft matrix. In tin-base babbitt, the constituents tin, antimony and copper form a two-phase system having hard crystals of antimony-tin and tin-copper intermetallic compounds supported in or by a soft matrix consisting of a solid solution of tin and antimony.

Traces of inferior bearing metal usually have an adverse effect on an alloy. An example is the harmful effect of small amounts of zinc in babbitt. Generally, if the contaminant is a metal which goes into solution with the bearing material, the effect is harmful. If it can be precipitated out by suitable heat treatment it will no longer be harmful, provided it has a higher melting point than the bearing material.

ARTHUR H. ALLEN

Process Controls in Spot Welding of Aluminum Alloys

Digest of "New Techniques for Spot Welding Aluminum", by William R. Gain, *Light Metal Age*, Vol. 13, June 1955, p. 19-35.

ADVANTAGES of spot welding as a method of joining aluminum alloy components of aircraft structures include flush joint surfaces and good sealing qualities for pressurized fuselages without adding weight to the design. On the other hand, cost of spot welded joints is increased appreciably by the necessity for thorough cleaning of parts before welding, and for strict adherence to

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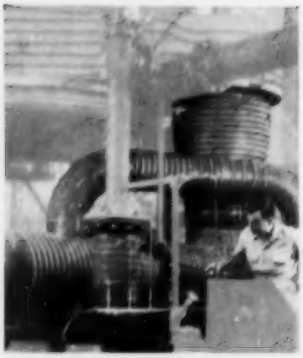

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Throughput for air: 1,000,000 micron-liters/sec.
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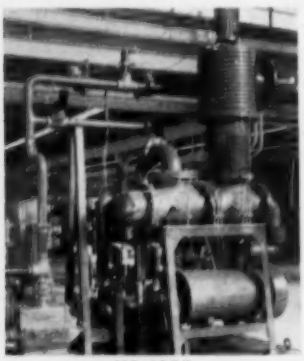

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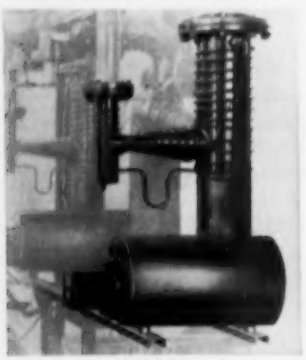

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Welding Aluminum . . .

production controls and sample testing that is required throughout a welding sequence.

Where large numbers of welds must be made it is possible to reduce costs below riveting. In one instance involving a number of large body panels with lap joints having two rows of spot welds, average cost was only 0.022¢ per spot. This included cost of shearing the skins, layout and assembly time, cleaning the component parts, setting up spot welding machines, making required production tests and actual spot welding operations.

As indicated, process controls are complicated. In developing a spot welding schedule for Class SP (special purpose) spot welding, it must be demonstrated on each joint combination that the static joint strength exceeds 50,000 psi. and that failure occurs in the base metal, not by shearing the spots. This is checked by welding and testing panels. Five specimens are tested for ultimate static strength and two are examined metallurgically. The former must average 50,000 psi. or greater and no specimen may fail below 47,500 psi. Metallurgical examination must show the welds to be free from internal defects such as cracks, voids or porosity, and to be within the penetration limits of 30 to 80% of the base metal thickness.

A 20-weld single-spot shear-test panel is welded, cut and tested for each interface to establish the single-spot shear strength average and to prove that at least 18 of the 20 welds fail within 12½% of their average, and the remaining two must be within 25% of the average.

Surface preparation for this class of welding covers chemical cleaning and deoxidizing to obtain a surface resistance not to exceed 50 microhms, followed by subsequent wire brushing of the faying surfaces. The latter must be done within 8 hr. after chemical deoxidizing and the parts must be assembled within a half-hour after wire brushing. Welding must be completed within 24 hr. after deoxidizing.

During production a three-weld single-spot shear-test specimen for each interface and a three-weld macrosection are spot welded, cut and tested before starting to weld

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each production joint. The average strength of the three-weld single-spot shear specimen cannot be more than 3% below the average strength obtained during certification of the joint being tested, and none of the three may fail at a strength below the minimum single-spot strength obtained during certification.

The macrosection is cut, polished, etched and examined. Acceptable quality with respect to penetration and internal defects must be indicated. After examination, the specimen is cut into a 3/32-in. strip which must show no evidence of cracking as it is bent through 45° across the face of the weld.

Shear and macro tests, in addition to those made at the beginning of each welding sequence, are required at the following stages: *(a)* within ½ hr. after the beginning of each shift; *(b)* at intervals not to exceed 2 hr. for each sheet thickness combination on each machine set-up, or at the end of the run if less than 2 hr. has elapsed since the last test; *(c)* at each change in machine set-up or change in machine settings; *(d)* upon replacement of welding electrodes; and *(e)* at each change of alloy, condition or sheet thickness being welded.

Finally, a check must be made every three months on ultimate tensile strength for the combination of sheets having the minimum total thickness of "pile-up" and the combination having the maximum total thickness of pile-up on each machine and each shift on which the machine is used in production.

Similar test procedures must be observed for Class A spot welding, covering such parts as floor beams and floor panels. This work is done on roll spot welders at a speed of 90 to 110 spots per min. with 0.62-in. spot spacing and external flood cooling to minimize warpage.

A test program is under way to determine fatigue life of spot welded joints. Preliminary conclusions are that the fatigue life of a "special-purpose" joint is greatly increased by the addition of a third row of spot welds, although this does not develop any appreciable increase in static joint strength.

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Strain Aging of High-Purity Iron

Digest of "The Strain Aging of Pure Iron", by B. Jones and R. A. Owen-Barnett, *Journal* of the Iron and Steel Institute, Vol. 180, May 1955, p. 20-23.

FOLLOWING an extended investigation of the aging of mild steel strip after temper rolling and tensile straining, a comparison study of the aging characteristics of two high-purity irons containing less than 0.004% carbon, 0.002% nitrogen, and 0.010% oxygen was made. Si, Al and Mn were all below 0.005%.

The pure iron strip was cold rolled to 0.05 in. thick. Although mild steel recrystallizes at 1110° F. after heavy cold reduction, it was found that the pure iron did not completely recrystallize below 1700° F. All samples were therefore vacuum annealed for 2 hr. at 1700° F. for uniform grain size and then reduced 60% in thickness. This strip was cut into 6-in. lengths and machined into standard strip tensile pieces with a 2-in. gage length. Test pieces were then reannealed at 1700° F. before the straining operations.

Some of the annealed test pieces were temper rolled 2.4% and aged various times before testing. The results are as follows:

Treatment	Yield	Ultimate
Annealed	18,600	35,000
Temper rolled	16,600	34,300
Aged		
30 days at 70° F.	22,400	35,800
24 hr. at 170°	22,400	36,000
24 hr. at 212°	22,600	35,800
3 hr. at 390°	22,600	35,800
1 hr. at 480°	22,000	35,600

As usual, temper rolling removed the yield point (drop of beam), and weakened the iron. On aging one month at 68° F. the yield point returned and hardness increased from Vickers 66 to 80. Aging showed almost identical results at various temperatures, indicating that pure iron ages almost completely at 70° F. after resting one month. The rate of aging in pure iron is thus much more rapid than in mild steel, the properties of which change continuously over a period of one to three years after straining.

The more rapid rate of aging in pure iron as compared to commercial

Are you looking for better methods for stripping paint?

What's the best way to strip metal parts in large volume?
See page 9

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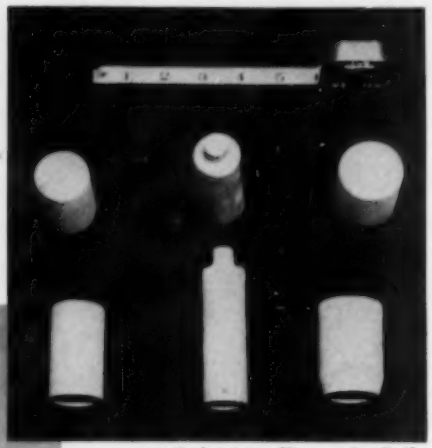

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Analysis 35% Ni — 15% Cr

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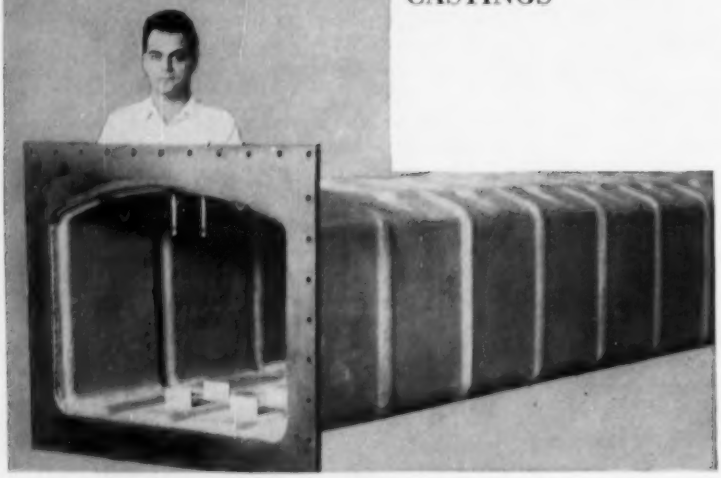

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Strain Aging . . .

mild steels is explained by the authors as being due to greater freedom of the carbon and nitrogen to migrate in the pure iron lattice in the absence of other interfering elements such as manganese. On the assumption that the equilibrium solubility of carbon in pure iron is only 10^{-7}% and nitrogen 0.0002% both samples of the "pure" iron were supersaturated with both of these elements which promote aging. Internal friction measurements also confirm this opinion.

Since even these minute amounts of carbon and nitrogen in the high-purity iron were responsible for almost as much strain aging as occurs in ordinary mild steel, one of the iron samples was annealed in moist hydrogen for 16 hr. at 1435° F. in order to reduce the carbon and nitrogen. After this, one piece was tested in tension immediately and another was stretched 6%, then aged 1 hr. at 480° F. and tested. No evidence of any yield point or any aging was observed in either sample. The yield strength is very low, since the stress-strain curve is curved from the origin of loading.

Conclusions — Pure iron with a large grain size (about 0.18 mm.) and containing 0.0002 to 0.004% carbon and 0.001 to 0.002% nitrogen, exhibits a well-defined yield point in an autographic stress-strain curve.

A fairly appreciable amount of strain aging occurs after temper rolling or tensile straining.

The rate of aging of pure iron at room temperature after temper rolling is considerably greater than with commercial low-carbon steels. Artificial aging treatments of temper rolled pure iron at 165 to 480° F. give similar results to those after aging for 1 month at 70° F. The authors think this is due to the ease of migration of the carbon and nitrogen atoms in a crystal lattice relatively free from such atoms as manganese which tend to restrict their movement.

Residual stresses induced by rolling do not appreciably retard the rate of aging.

Annealing in moist hydrogen eliminates the yield point and strain aging, since carbon and nitrogen are reduced to extremely low values.

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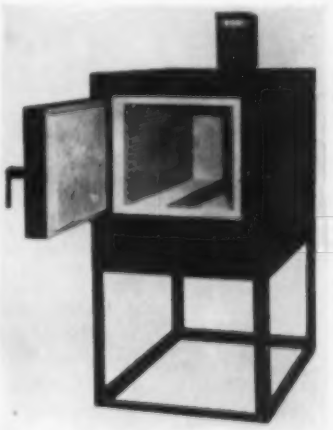

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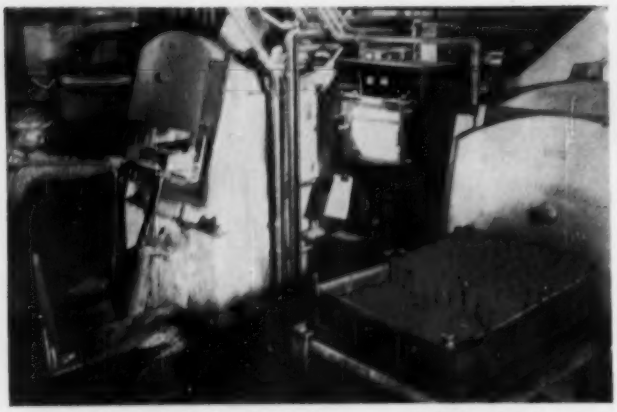

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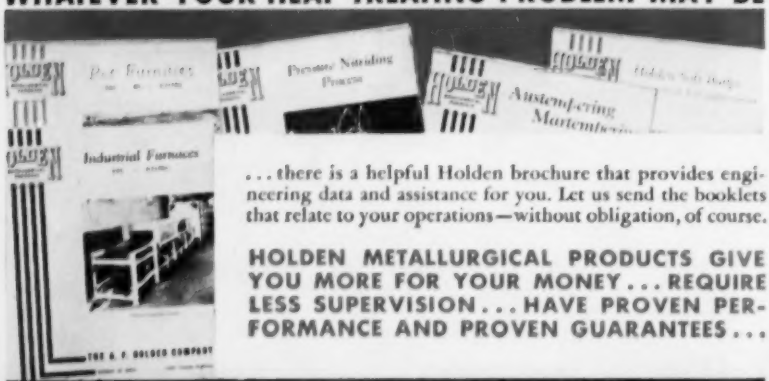

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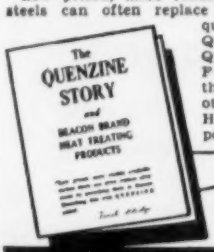

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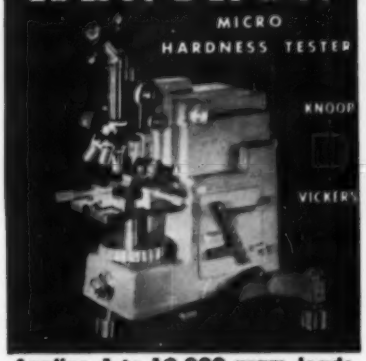

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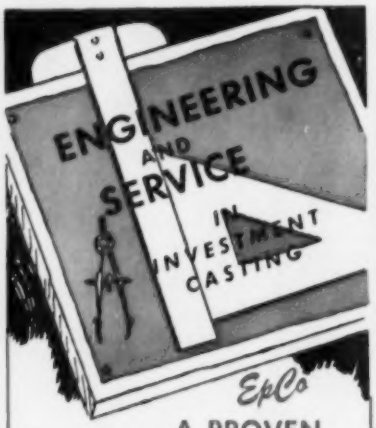

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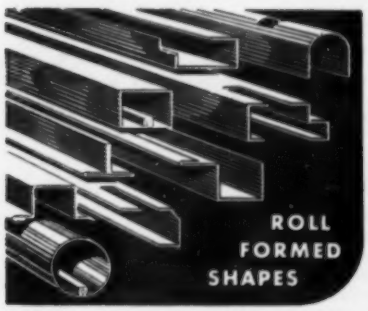

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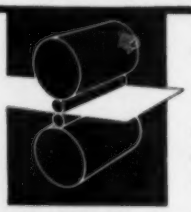

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Geneva Conference . . .

(Starts on p. 79)

as much as 1% fission of all the atoms in the fuel in the element. The limits of usefulness of ceramic fuel elements are within the practical range; important systems include beryllium oxide, uranium oxide, and graphite-uranium oxide. The moderating materials graphite, beryllium oxide, beryllium, and water have been studied in detail and their range of applicability thoroughly established.

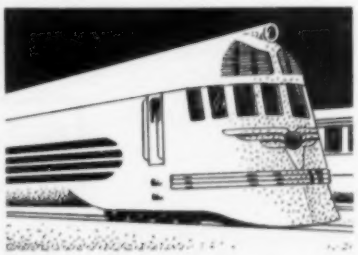
Work in the U.S.S.R., discussed by Zdanoff, covered nearly all the basic phenomena known to occur during irradiation of uranium and uranium-rich alloys. Most noteworthy was his report of a phase transformation promoted by irradiation in a uranium alloy containing 9% Mo. Such an alloy quenched from near 1475° F. is retained in a body-centered cubic structure. On aging, the structure decomposes by a typical eutectoid reaction into an alpha-uranium phase and an epsilon-prime phase, which is tetragonal and in which the uranium and molybdenum atoms are ordered. Upon irradiation this two-phase structure reverts to the single-phase gamma structure.

Distortion of uranium under irradiation and the possibility of swelling at moderately high temperatures were discussed by Pugh of the United Kingdom. Two mechanisms have been proposed to explain distortion — *(a)* pressure in a microscopic region exerted by atoms heated by a fission spike, and *(b)* a mechanism involving both the anisotropic diffusion of interstitial atoms and vacant lattice sites produced by the disordering effects of fission recoils. The first theory predicts the proper direction of distortion, namely, along the b-crystalline axis in alpha-uranium, but suffers from the fact that it requires dislocations to move at many times the velocity of sound, which appears improbable. Experimental information does not provide an adequate basis for a choice between the two hypotheses.

Some noteworthy work in the U.S.S.R. considered the effects of irradiation on structural materials including copper, zirconium and steel. Other than the well-known increase in yield strength and decrease in ductility, of particular note was the grain growth in copper and the recrystallization in zirconium observed under irradiation at temperatures below that at which one would expect such things to happen. Confirmation of these observations is required.

(It appears to this reviewer that all of the known phenomena resulting from irradiation have been observed and studied to some extent in Russia, but no reasons for these effects were given in their papers or in the oral discussions. Unfortunately, these discussions were rather badly inhibited by language difficulties. One might gather that the Russian investigators feel that theoretical explanations will be the objective of their future work.)

Seitz and Koehler's theory of lattice displacements during irradiation can permit one to estimate the number of atoms displaced by fast particles due to primary and secondary collisions. Dienes of the Brookhaven National Laboratory showed that the total number of displaced atoms in graphite could be measured by neu-



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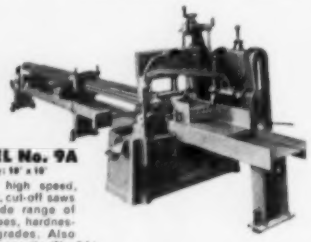

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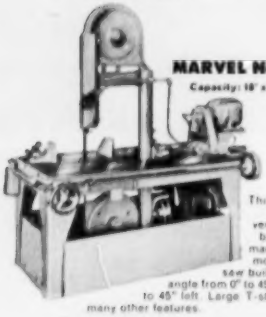

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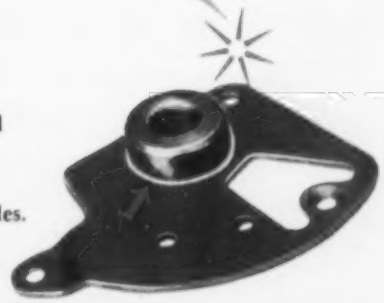
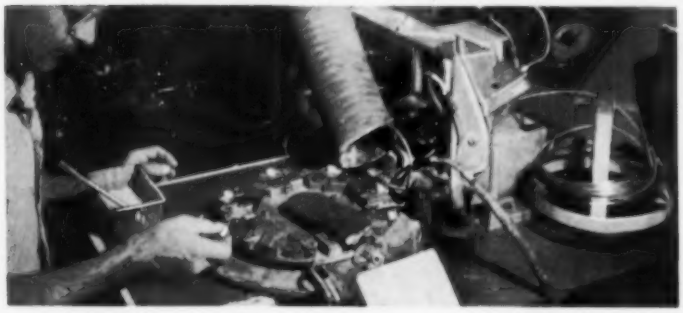
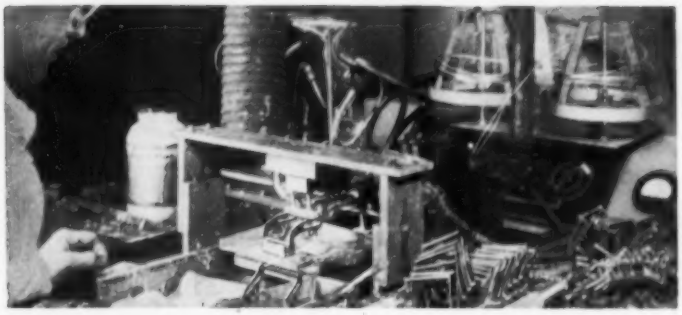


Bushing is induction brazed to case hardened stamping on turntable fixture with EASY-FLO 45 wire automatically fed and positioned at joints. Operator merely loads parts. Time per assembly — 3½ seconds — 500 per hour.





Frame above is made by brazing side pieces to rods on induction coil setup shown. Output of 120 frames (480 joints) per hour is easily maintained. At left — a few other parts similarly produced.

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METALLURGICAL SPECIALISTS

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tron diffraction and that this number agreed reasonably well with that calculated by the theory. In metals, the number of defects produced cannot be determined or correlated so clearly.

Varley of the United Kingdom discussed the basic principles underlying such effects as the increase in yield point due to the pinning of dislocations by defects, and the production of color centers and other crystal defects in ionic crystals.

French work on graphite, crystalline quartz, and lithium fluorides, as reviewed by Mayer, was centered on the velocity of sound, its change during irradiation, and subsequent annealing.

Crawford of the Oak Ridge Laboratory gave a comprehensive review of irradiation effects in ionic and covalent solids, particularly in crystalline quartz and in several of the important silicate minerals. It appears that the oxygen atoms are the most easily displaced in these crystals, and that the ease of their displacement corresponds with our notions of the relative binding of the oxygen. The density of the quartz decreases with irradiation, and upon annealing at 1500 to 1800° F. the crystal returns almost to its former density. Oddly enough, the crystal tends to retain its external dimensions and an array of cylindrical voids of very small diameter is found parallel to the original c-axis of the crystal.

Hennig and Hove showed very nicely the mechanism responsible for the very interesting and pronounced irradiation effects in graphite. The picture was pieced together from *(a)* results of irradiation at liquid air temperatures, followed by heating to successively higher temperatures; *(b)* results at room temperature and higher described by Woods; *(c)* measurements of the electrical and magnetic properties of graphite, of crystalline parameters and of thermal conductivity; *(d)* studies of the diffusion of radioactive carbon tracer atoms in the graphite crystals; and *(e)* the paramagnetic resonance produced by irradiation. Irradiation displaces carbon atoms one at a time; they take up interplanar positions, and they subsequently move between the

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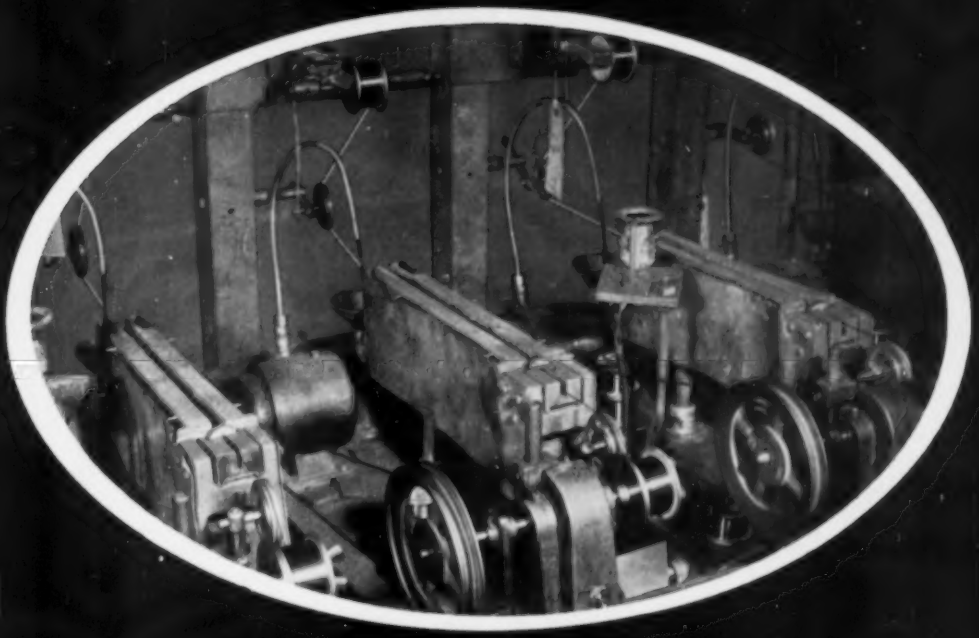

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planes and become charged by trapping electrons. At slightly elevated temperatures, perhaps 300 to 400° F., these charged interstitial atoms can combine with one another and with the vacancies left in the planes. Finally, but only at temperatures of the order of 1830° F. and above, all the interplanar atoms are gotten rid of, but still higher temperatures (3275° F.) are required to remove lattice vacancies.

Metal Production

Uranium and Thorium – Concentration of ores and reduction to metals were the subject of two sessions. Methods for producing uranium metal are rather similar in all countries at the present time, namely, pure UF_4 is produced and then reduced with either calcium or magnesium metal in a properly lined, closed vessel. Methods for producing the fluoride vary from country to country depending on the availability of fluorine compounds. The exact techniques to produce proper heat to initiate the reduction reaction, and to separate slag from the metal, vary also. Russian papers said that thorium metal powder is produced by electrolysis of fused salts, and by reduction of thorium oxide by calcium. (The latter reaction and the working of the powders follows rather closely that by Marden of Westinghouse a number of years ago.)

Graphite – Very pure graphite appears to be available to all countries. Interestingly enough, the French are more optimistic about producing highly dense graphite on a commercial basis than we are in the United States. For proprietary reasons, the French did not discuss their production methods.

Zirconium production was reviewed completely by Shelton of the U.S. Bureau of Mines. This technology has come from the laboratory to commercial stage in the last ten years, and depends on separating hafnium from its lighter but very similar brother zirconium and reducing the zirconium fluoride to metal by the Kroll process. Subsequent arc melting produces forgeable ingots. Fabrication methods for zirconium are straightforward except that many precautions are necessary to keep oxygen, nitrogen, and other harden-

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ing agents out of the metal during heating or working. The U.S. Atomic Energy Commission is currently asking for bids for the delivery of 200 tons of zirconium yearly in addition to the 100 tons annually now being delivered from Carborundum Metals Co.

Beryllium technology was discussed by men from U.S.S.R., United States, France and Argentina. Its use in reactors has been rather specialized since the cost of metallic beryllium in useful shapes is now too high for use in commercial reactors. The same may not be true of beryllium oxide.

Reactor Fuels

The physical metallurgy of uranium and thorium, and the fabrication of fuel elements, occupied only one session – scarcely adequate to discuss one of the dominant subjects of the reactor business. (This statement is made with no rancor on the part of the writer who participated in this discussion!) A top-notch paper on the physical metallurgy of uranium by Foote of Argonne had to be summarized in 20 min. He was able to say a little bit about textures and deformation mechanisms for alpha-uranium, but had to omit much of the very interesting information on transformations in uranium and its alloys, its distortion under thermal cycling, and many other subjects important and interesting both to reactor designers and metallurgists. Similarly, the discussion of thorium and its alloys was far too short, although this subject is somewhat less complicated.

The present writer attempted to summarize the metallurgy of reactor fuels by describing the following types of fuel systems: *(a)* those based on alpha-uranium, *(b)* dispersions of uranium and uranium compounds of well-behaved metallic matrices, *(c)* ceramic fuel elements, and *(d)* fluid fuel systems. Materials and processes for handling these systems could be enumerated briefly and some of the physical, chemical, and metallurgical problems (distortion of uranium, irradiation effects, interdiffusion at high temperatures, and corrosion) were presented as interesting problems, with partial solutions showing the conditions under which some reactors could be operated.

Weber, of Knolls Atomic Power Laboratory, showed how to design and fabricate optimum dispersion-type fuel elements by achieving a proper particle size and distribution of the second phase within the supporting metallic matrix. Cunningham's paper showed in some detail how to manufacture the type of fuel elements used in the Materials Testing Reactor at Arco, Idaho, and also used in other pool-type research reactors. In particular, he described how the elements for the reactor on display at Geneva were made,* by processing powders, rolling, roll cladding, flux annealing and brazing.

Recovery or reprocessing of reactor fuels was summarized by Lawroski of Argonne. So far, removal of fission products and recovery of plu-

*This was also covered by the paper by Coobs and Manly read before the A.E.C.-A.S.M. Conference on Powder Metallurgy in Atomic Energy at Philadelphia last October.

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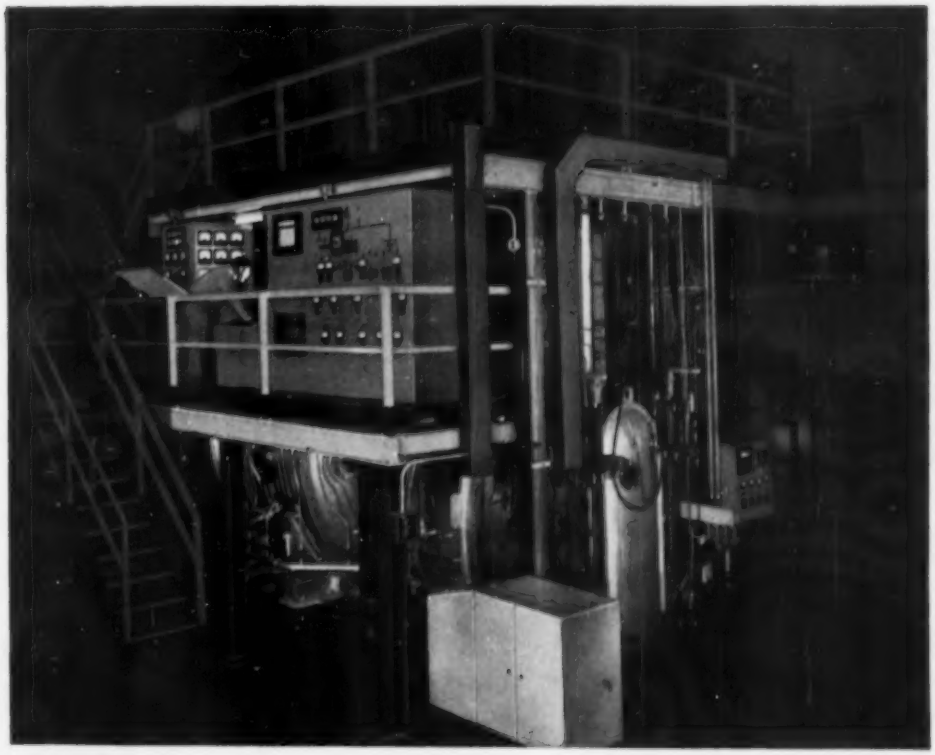

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tonium have been done by aqueous chemical methods. However, uranium and thorium can be partially decontaminated while in the metallic state. Such metallurgical processes consist of melting uranium in contact with a solid such as uranium oxide into which many of the fission products tend to partition. By this means, perhaps 90% of the fission products can be recovered. Similarly, fission products and plutonium may be removed by equilibrating a metal melt with proper molten salts. Liquid metal extraction presents a third possibility, and a fourth, although not very promising, is distilling or vaporizing the fission products. None of these methods achieves the high recovery of aqueous methods now used, and hence they are not suitable for producing weapons-grade plutonium — or in fact recovering a uranium which may now be handled by ordinary methods. However, the development of simple fuel elements, fabricated by remote methods, may use the partially refined fuel and so avoid the costly aqueous methods.

Tensile Strength and Endurance Limit of Nodular Iron

Digest of "Tensile and Fatigue Tests on Hardened and Tempered Nodular Irons", by G. N. J. Gilbert and K. B. Palmer, Report No. 404, *Journal of Research and Development*, British Cast Iron Research Assoc., Vol. 5, April 1955, p. 604-615.

THE British Cast Iron Research Association has summarized the published results of seven independent investigations of the tensile properties of heat treated nodular irons, and also presented their own tensile and fatigue results. The previously published work covered a wide range of chemical compositions. Test specimens were hardened by quenching in oil and tempered ¼ to 3 hr. at various temperatures between 700 and 1350° F. The compositions and heat treatments gave tensile strengths from 70,000 to 218,000 psi., and elongations between 1 and 18%. The strengths as cast or annealed were near the lower

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Ni	.....	.....	0.20%	.....
Cb+Ta	0.50%	.....	0.50%	.....
Ti	0.20%	.....	.....	0.50%
Si	0.10%	0.10%	0.10%	.....
Mn	0.10%	0.10%	0.10%	.....
V	.....	0.10%	.....	.....
Zr	.....	.....	.....	0.20%
Sn	.....	.....	.....	0.10%
W	.....	0.20%	.....	0.30%
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($\times 10^{-6}$/°C up to 650°C)	4.5-7.2
Magnetic Permeability (μ Induction)	1.5-3.0
RANGE OF MECHANICAL PROPERTIES OF VARIOUS GRADES	
Hardness (Rockwell A)	85-93
Hardness (Rockwell C)	67-82
Hardness (Knoop-K100)	1700-2100*
Transverse Rupture (psi)	175,000-385,000
Young's Modulus of Elasticity (psi)	61,600,000-94,300,000
Compressive Strength (psi)	518,000-800,000
Torsional Strength (Shearing Stress psi)	100,000-186,000
Tensile Strength (psi)	To 150,000
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Nodular Iron

limit of this range, and the elongation of annealed specimens was 14 to 24%.

In general, the strength increased as the tempering temperature was decreased to about 800° F., and since the ductility was negligible when the tempering temperature was lower, the strength did not increase further with still lower tempering. Tempering above 1100° F. produces a dispersion of small graphite spherulites through the alloy. High phosphorus tends to decrease this graphitization, and the elongation is also decreased by phosphorus. A slight increase in phosphorus above 0.02% improves the strength, but with phosphorus above about 0.1%, the strength decreases as well as the elongation.

Since the tensile properties after hardening and tempering seem appropriate for crankshafts an investigation of the fatigue properties was undertaken. The iron used contained 3.17% C, 1.96 Si, 0.29 Mn, 0.031 S, 0.095 P, 0.61 Ni, 0.067 Mg and 0.015 Ce. Melts of 270 lb. were made in an oil-fired furnace, treated with a nickel alloy containing 16% Mg and 3% Ce, followed by 80% FeSi, and cast into the form of keel blocks from which 9/16-in. round bars were cut for heat treatment. The test bars were quenched in oil from 1650° F. and tempered 1 to 4 hr. at temperatures between 750 and 1110° F. Photomicrographs show no ferrite, even as cast. After heat treatment the structure was martensitic with graphite nodules. When tempered at 1110° F. very fine nodular graphite, as well as spheroidized carbide, occurred in the structure, but when tempered at 1020° F. or lower the very fine nodular graphite was not observed.

The tensile properties as cast were 96,300 psi. tensile strength, 56,000 psi. yield strength and 3% elongation. The hardness was Brinell 254. After hardening and tempering 1 hr. at 1110° F. the hardness rose to 314, the tensile strength to 139,300 psi. and the yield strength to 105,700 psi., the elongation remaining at 3%. Tempering 4 hr. instead of 1 hr. decreased the strength slightly but raised the elongation to 5%. Tempering 4 hr. at lower temperatures gave lower elongation – down to zero at

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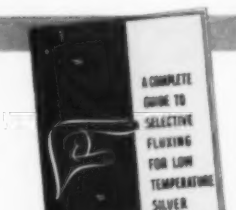

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Fatigue and Tensile Tests on Nodular Iron

	Tensile Strength	Fatigue Limit	
		Unnotched	Notched
As cast	96,300	40,300	25,800
Quenched and tempered 2 hr. at 1110° F.	134,600	49,300	30,200
Quenched and tempered 2 hr. at 1020° F.	149,400	49,300	28,200

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Pinholing in Nodular Iron Castings

Digest of "Pinholing in Nodular Iron Castings", by J. Gittus, Report No. 403, *Journal of Research and Development*, British Cast Iron Research Assoc., Vol. 5, No. 2, April 1955, p. 594 to 603.

Subsurface pinholes are sometimes serious defects in sand castings of nodular iron, and various methods of decreasing their severity have been investigated. An iron containing 3.2% C, 1.8% Si, 0.3% Mn, 0.03% S and 0.08% P gave sound castings in the form of 2 × 2-in. cylinders when poured in molds made of medium silica sand with 5% western bentonite and 2.5% water. When a nodulizing alloy was added to incorporate 0.7% Ni, 0.064% Mg and 0.019% Ce in the castings, and the treated iron was cast in the same kind of molds, pinholes were prevalent on shot-blasted surfaces. When 2% pelleted pitch was added to the molding sand, however, the nodular iron castings were sound.

Similar results were obtained when 6% superfine coal dust was substituted for the 2% pitch, and when several different molding sands with clay binders, and of various grain sizes, were used.

When silica-bentonite sand without pitch was used, the nodular iron cast at 2460 to 2510° F. showed more severe pinholing than when poured at 2370 or 2570° F.

When the test castings were 9 × 12-in. plates 1 in. thick, some pinholing of nodular iron was found even with pitch or coal dust in the

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Totally Enclosed Aluminum Oscillator Box	✓		✓		✓	✓	✓
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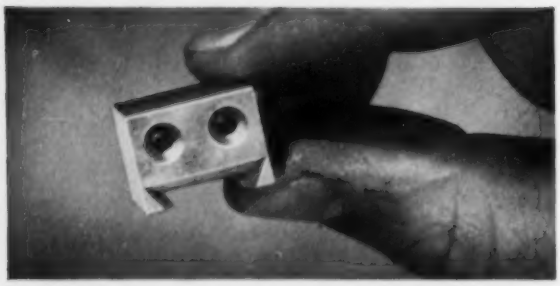

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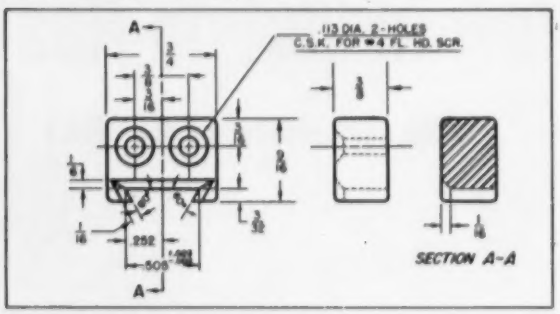

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Pinholing . . .

sand, but it was only about a fifth as severe as with the regular noncarbonaceous sand. Less than 2% pitch, or less than 6% coal dust was not at all effective. When the molds without pitch or coal dust were dried, pinholing was about half or a quarter as severe as in green sand molds. But some pinholes occurred on the upper surfaces of castings poured into open-top molds on which completely dry sand was spread on top of the molten metal after pouring. This is claimed to indicate that mold moisture is not the only factor causing pinholes. It should be noted that this experiment was made with open-top green sand molds, so that moist sand was contacted by the metal in pouring, even if the top surface was dry during solidification.

Boric acid in the sand had no effect on pinholing.

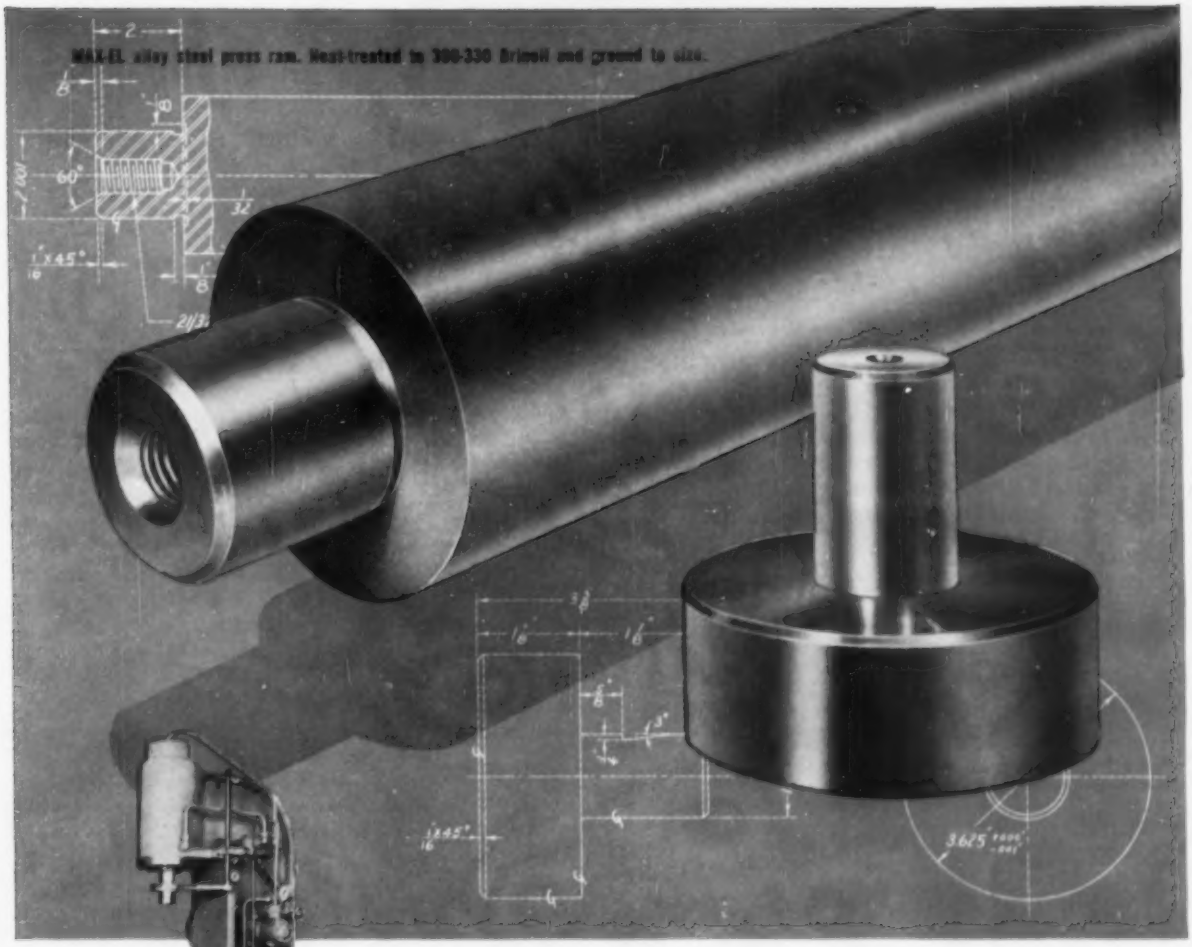
No pinholing occurred, even with natural noncarbonaceous green sand, if less than enough Mg were added to the iron to eliminate flake graphite (below 0.06% residual Mg). Also if at least 0.2% Al, 0.002% Te or 0.004% Bi were added with the nodulizing agents Mg and Ce, no pinholing occurred. The ladle additions of these elements had to be 50% greater. Additions of Sn or Zn had no effect. With only 0.0003% Te in the iron and 6% coal dust in the mold, pinholing was reduced almost as completely as with 0.0024% Te in the iron and a natural green sand mold.

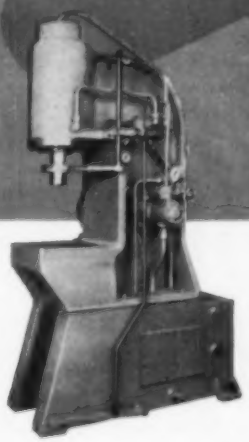
The use of a mold wash containing pitch prevented pinholing but plumbago did not.

Pinholing was most severe on the bottom surfaces of the 9 × 12-in. plates. Pouring speed as regulated by the size of the gate had no effect. Castings less than ⅝ in. thick had fewer pinholes, perhaps because they solidify too rapidly.

Photomicrographs of thin sections of pinholed castings, cut so as to include the surface layer with adhering sand, are presented to show that the gas bubbles are often nucleated on the tips of sand grains. The gas is probably produced by a reaction between the mold and the metal, related to the magnesium in the metal and moisture in the mold.

GEORGE F. COMSTOCK





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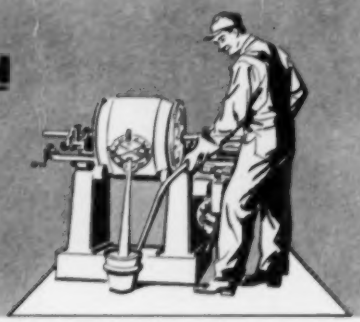

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British Developments in Special Steels

Digest of "Recent Progress in Alloy and Special Steels", by G. T. Harris and E. Johnson, *Metallurgia*, Vol. 51, January 1955, p. 17-23.

ALLOY steel developments in England during the 18 months preceding January 1955 are briefly discussed in this review. The advantages of the low-alloy high-strength steels for structural uses are noted, and the replacement of molybdenum by vanadium in two of them is reported to improve the strength and impact resistance because of grain refinement. By careful heat treatment and inspection, alloy contents are being reduced. The properties of these steels at low temperatures are being studied extensively.

For use in aircraft there is increasing interest in steels having extra-high tensile strength (268,800 psi. minimum) with at least 6% elongation in 2 in. and 20 ft-lb. Izod impact value. The titles of specifications for several steels meeting these requirements are listed, but their compositions are not disclosed. Treatment of quenched parts in liquid nitrogen increases strength without loss in ductility. Machining of such steels should be completed before heat treatment.

For cold work such as punching, pressing, and thread rolling, high speed steels based on tungsten and molybdenum but with lower carbon than usual, and high-carbon high-chromium steels with molybdenum and vanadium, are being used or recommended. Low-carbon 5% Cr steel has been developed for molds that can be annealed for machining and subsequently carburized and hardened.

Creep resisting alloys, such as those containing a large percentage of cobalt, are being used for hot extrusion dies. Another good material for this use is a steel containing 12% W and 12% Cr. For precision forging dies 5% Cr steel with molybdenum and vanadium is best.

Wear resistant high speed steels for tool bits and milling cutters, containing 1.25 to 1.50% C, 4.6 to 4.7% Cr, 12.5 to 13.5% W, 3.75 to 5% V, and possibly also 5% Co, are increasingly popular. Tempering

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British Steels . . .

hardened drills at 660 to 1030° F. in steam to produce a blue oxide surface reduces the friction between the tool and the work. For gear hobs a high speed steel containing 0.12% sulphur is claimed to give superior cutting life because of lubrication by the sulphide at the cutting edge.

New equipment and research on heat treatment are reported. New work on temper brittleness is mentioned, with an explanation based on segregation of solute atoms at the grain boundaries in both austenite and ferrite.

An austenitic steel containing copper and molybdenum is widely used for corrosion resisting castings. Austenitic corrosion resisting steel can be made with 18% Cr and 6 to 14% Mn provided 2 to 6% Ni and 0.10 to 0.15% N are present; otherwise 13% Mn is required for 13% Cr.

Precipitation hardened stainless steel is mentioned, with special reference to the 21% Cr, 12% Ni type containing 0.5% C and 0.3% phosphorus. Patents are reported on the use of 4% Cu, or working at subzero temperatures, for promoting the work hardening of austenitic stainless steel. In a valve steel (called X.C.R.) sigma formation has been utilized for hardening.

An iron-base alloy, G 42 B (28% Cr, 15% Ni, 24% Co, and 32% Fe), is beginning to replace the nickel-base precipitation hardened alloys for turbine blades operating above 1650° F. By warm-working this steel, 100-hr. life-to-rupture is attained at 1650° F. and 16,900 psi. Vacuum melting is being used for experimental heats of some of the wrought turbine-blade alloys.

Wrought turbine blades are preferred over precision-cast blades in England, because average values of high-temperature properties for the castings must be reduced 15% for safety where creep is the limiting factor, and 30% where fatigue is of major importance. Nondestructive testing of all cast blades is recommended. Vacuum melting and casting seem to reduce the scatter in test results.

For stationary nozzle vanes, cast alloys are now used in England. A high-carbon alloy containing over 60% Ni is the latest development for this use because its resistance to thermal shock is good due to low thermal expansion.

Ferritic turbine disks are now used rather than austenitic. Modified 12% Cr steel with high proof stress and adequate creep strength up to 1110° F. is preferred to the Discalloy (14% Cr, 25% Ni, titanium-hardened) so widely used for these parts in America. A forging 35 in. in diameter has been made of the modified 12% Cr steel.

Checking steel for hydrogen content during manufacture and processing is becoming more common. Vacuum-fusion gas analyses, rare-earth additions to improve working properties, use of magnesium in austenitic steel melts, hot extrusion of steel with lubrication of the die by molten glass, and continuous casting, are also mentioned as new developments.

G. F. Comstock

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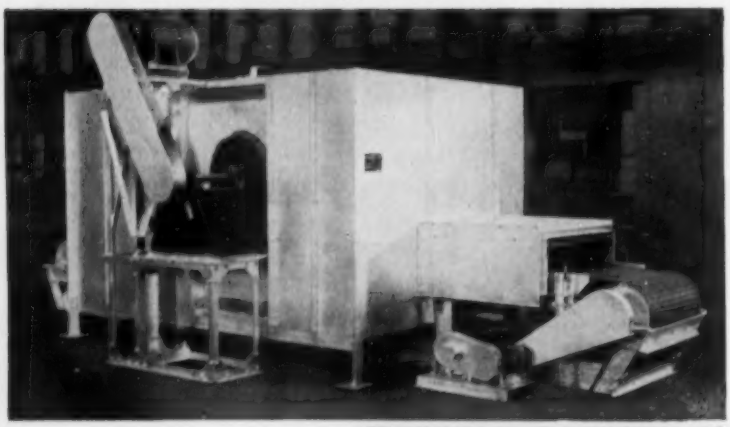

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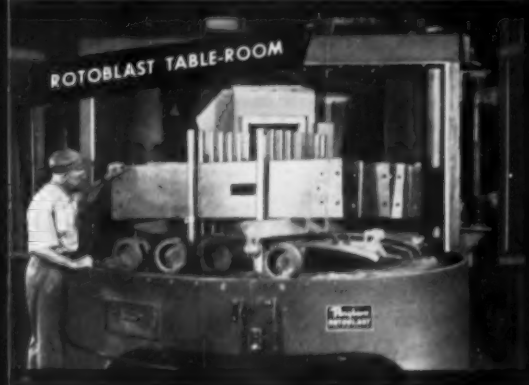

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Strengthening Stainless Steels

Digest of "Some Recent Developments in Stainless Steels", by J. I. Morley, *Journal* of the Birmingham Metallurgical Society, Vol. 35, June 1955, p. 187-212.

THE METALLIC skin of very high speed aircraft must be strong and rigid at temperatures up to 570° F. and aluminum alloys do not meet these requirements. At least one commercial titanium-base alloy has an excellent strength-weight ratio but is not rigid enough; its elastic modulus is too low. Precipitation hardened 17 Cr, 7 Ni steel, and 0.11 C, 11 Cr steel containing 0.75 Mo, 0.15 V and 0.5 Cb (designated as No. 448) are superior up to 570° F. in both respects to the cold rolled Ti-stabilized 18 Cr, 8 Ni steel often used in England for aircraft structures.

The No. 448 steel is not as strong as quenched and tempered 0.2 C, 12 Cr steel but has better impact resistance, ductility and weldability. Less delta ferrite occurs in the structure of the 448 steel and the martensitic transformation temperature is high so it can be welded without preheating. The Mo, V, and Cb carbides delay softening in tempering. The tensile strength is 197,000 psi. after oil quenching and tempering up to 930° F., and 157,000 psi. may be attained on tempering above 1100°.

The corrosion resistance of 448 in either tap water or 3% NaCl solution is superior to that of 13% Cr steels with 0.06 to 0.29% C. Representative mechanical properties of 0.064-in. sheet are shown in the table on p. 178.

The modulus of elasticity of hardened 0.036-in. sheet falls from 31.4 million psi to 26.8 after 4% strain, but after 1 hr. at 750° F. it rises again to 29.6 million psi.

Fully austenitic stainless steels that can be hardened by precipitation usually have high carbon up to 0.5% and sometimes Ti, Al, Be or B. They are either difficult to hot work or subject to intergranular carbide precipitation and are not as useful as the partially ferritic (or martensitic) 17 Cr, 7 Ni steels which can be formed in a soft condition and hardened by heating at about 1020° F. The low-carbon alloys with up to 1% Ti or Al have better marine corrosion resist-

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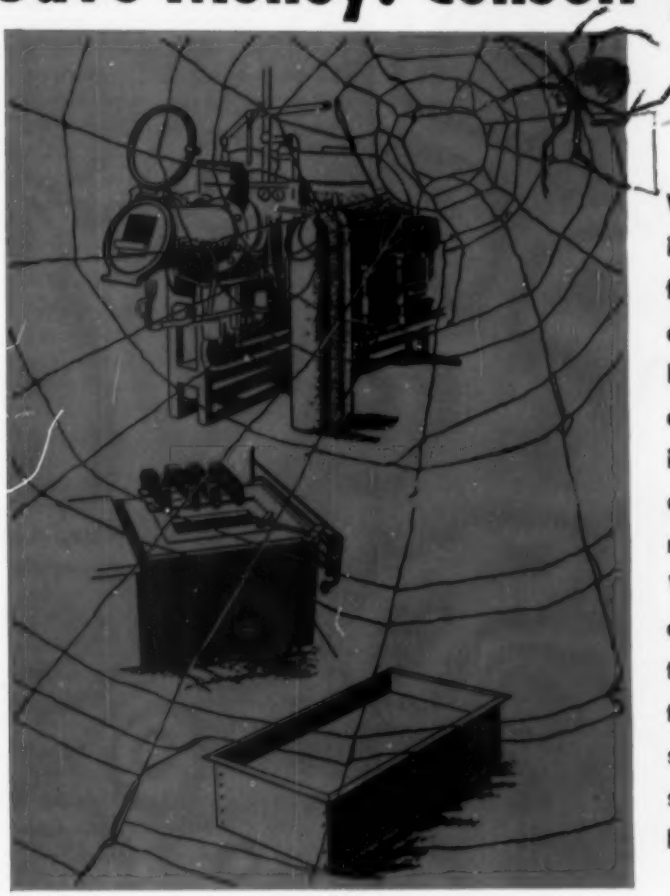

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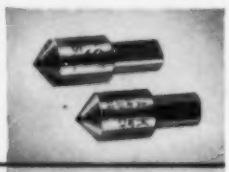

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Stainless Steels . . .

ance than the 11% Cr steel previously discussed.

The 17-7 steel with about 0.60% C plus N forms martensite only below 32° F.; with the addition of Ti and Al martensite forms between 250° F. and room temperature and the excess Ti and Al form compounds that harden the steel by precipitation on reheating between 660 and 1020° F. "Stainless W" containing Ti is always martensitic at room temperature, and when sheets are stretcher flattened their ductibility is low. "Armco 17-7 PH" contains Al and no Ti; its carbon is not stabilized so that the martensitic transformation is depressed below room temperature and stretcher flattened sheets are ductile. They can be hardened by sensitizing at 1290° F. to precipitate carbides and permit martensite to form, and then heating at about 930° F. to precipitate an aluminum compound in the martensite. When a sensitizing treatment is applied to 17-7 steel containing Ti, however, the subsequent precipitation hardening is decreased.

Precipitation hardened "Stainless W" has yield strength of about 150,000 psi. even up to 570° F., and the same elastic modulus in tension and compression. It is also highly resistant to steam corrosion, and is not susceptible to intercrystalline attack in boiling acidified copper sulphate.

Ductile stretcher flattened sheets of the 17 Cr, 7 Ni, 1 Al steel may be precipitation hardened at 930° F. not only after sensitizing at 1290° F. but also after cooling 2 hr. at −108° F. or after cold working by 10% extension. All three treatments cause martensite formation. With about 65% martensite, heat treatment for 2 hr. at 930° F. raises the hardness from Vickers 300 to about 400.

With the 17 Cr, 7 Ni, 1 Al steel, the best balance of high strength (179,000 psi.), yield ratio (90%), ductility (23%), and Izod impact value (60 ft-lb.) was achieved by sensitizing at −60° F., and tempering at 660° F. The properties were maintained fairly well up to 570° F., and were not impaired by 24 hr. at −40° F. or 480° F. Precipitation hardening for 1 hr. at 1020° F. after the 1290° F. treatment gives sufficient strength (about 160,000 psi. both longitudinal and transverse)

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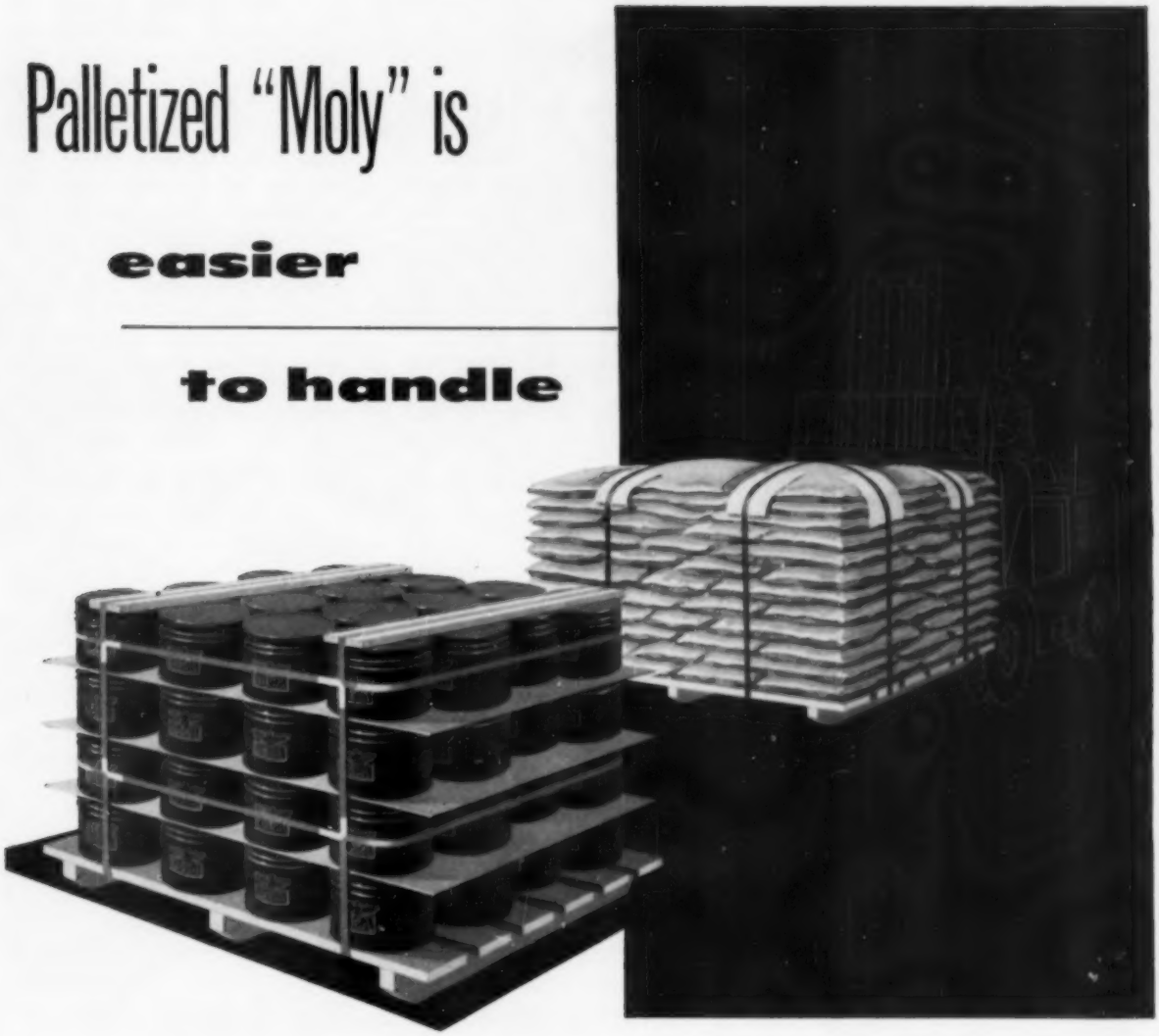

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Stainless Steels . . .

with reasonable ductility (around 10% elongation in 2 in.) Forming before the 1290° F. treatment results in lower final yield strength, and forming between the two treatments may give too high a yield ratio and low ductility. After hardening at 930° F. this steel is very susceptible to intercrystalline corrosion and also to corrosion by salt spray.

Sensitizing at −60° F. and tempering at 660° F. give useful strength and ductility but the fatigue strength is then only about 67,000 psi. as compared with 90,000 psi. after the 1290° F. and 1020° F. treatments. Welds in sheets sentitized by cold treatment may not respond to precipitation hardening. Welds made before the 1290° F. treatment are susceptible to intercrystalline corrosion, and if made after treatment, hardening is not uniform.

Cold working a stainless steel such as 18-8 Ti is the simplest and most common method of attaining high strength. Such cold worked steels, however, have much lower yield strength in compression than in tension, and only 25.8 million psi. elastic modulus. Their fabrication is more difficult and they are likely to soften near welds.

Steels that contain 0.09 C, 17 Cr, 7 Ni, and 0.03 N (Type 301), or 0.06 C, 17 Cr, 4.5 Ni, 6.5 Mn, and 0.12 N are reported to have 28 to 37% higher strength than 18-8 Ti when cold rolled, with no lower ductility. The Cr-Ni-Mn-N steel has the best ductility for a given cold rolled strength. This is advantageous in forming, but susceptibility to intercrystalline corrosion near welds is a detriment.

Production of high-tensile stainless steels will involve adherence to specially narrow composition ranges.

G. F. Comstock

Mechanical Properties of No. 448 Steel

0.064-In. Sheet	Yield Strength	Tensile Strength	Elongation in 2 In.
Soft sheet, air cooled from 1480° F.			
Tested at room temperature	49,300 psi.	82,300 psi.	26%
Tested at 570° F.	37,400	68,800	15
Hardened by air cooling from 1830° F. and tempered 1 hr. at 1110° F.			
Tested at room temperature	156,000	171,000	10
Tested at 570° F.	135,000	152,000	6

British Experience with High-Sinter Burdens

Digest of "Ironmaking with High-Sinter Burdens", by G. D. Elliot, J. A. Bond and T. E. Mitchell, *Journal* of the Iron and Steel Institute, Vol. 175, November 1953, p. 241 to 247.

For many years the Appleby-Frodingham plant in Lincolnshire had operated with a lean ore burden of 67% raw ore and 33% sinter for their blast furnace. The steadily increasing amount of fines arising from variations in the ore compelled the use of more than 33% sinter. Additional sintering capacity was installed and now 42% sinter is used. Eventually the burden will have to contain 63% sinter. Full-scale furnace tests to evaluate sinter burdens of 42%, 63% and 94% are reported in the table. With 94% sinter the furnace worked more evenly, iron analysis was more uniform, coke consumption was reduced, output was increased, sulphur troubles were greatly reduced, and blast temperatures as high as 1380° F. were possible.

The smelting of pig iron from

Effect of Sinter Content on Blast Furnace Operation

Sinter Content*	Coke†	Slag†	Flue Dust†	Iron Output‡	Blast Pressure	Temperature
35%	2260 lb.	2390 lb.	179 lb.	514 tons	15.2 psi.	820° F.
63	1954	2560	74	640	19.3	1040
94	1780	2530	176	667	19.3	1150

*Percent of burden. †Pounds per long ton (2240 lb.) ‡Long tons per day.

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these low-grade ores prior to the introduction of sinter in the burden has many features not found in normal rich-ore practice.

1. Hot blast temperatures above 840° F. caused hanging.
2. Blast pressures above 16 psi. caused the charge to stick above the bosh.
3. Blast volume could not be maintained during periods of stock hanging.
4. High iron output of uniform analysis was difficult to maintain.
5. Coke consumption was more than 2200 lb. per ton of iron.

With the high sinter charge hot blast temperatures up to 1380° F. could be used, blast pressures over 23 psi. (the limit of the present blowing engines) were possible and hanging of the charge largely disappeared. Even with the limit in blowing pressure of 23 psi., output has reached as high as 900 tons per day as compared to 500 tons per day without sinter. When larger blowing engines are installed, 1000 tons per day is anticipated. The authors state that the Rice rating on coke consumption rose from 70% to 93% with the full sinter burden. In addition the top temperature has not increased with this harder driving of the furnace and the ratio of CO to CO_2 has remained practically constant with different amounts of sinter in the blast-furnace burden.

Variation in sinter analysis because of the variation in ore is still troublesome. A very lean ore mix which yields a low-melting slag with a lime-silica ratio of 1.1 to 1.2 gives excellent results. Such a sinter acts as a premelted slag. Increase in either silica or lime in the burden raises melting temperature of the slag and upsets the blast furnace performance.

Another factor in British practice is the higher sulphur content of both the iron ore and coke as compared to American experience. The use of sinter versus raw ore charge is particularly advantageous in this respect. The sintering operation eliminates 70% of the sulphur in the ore mix and the 10% or more reduction in coke consumption further reduces the amount of sulphur entering the furnace per ton of iron produced.

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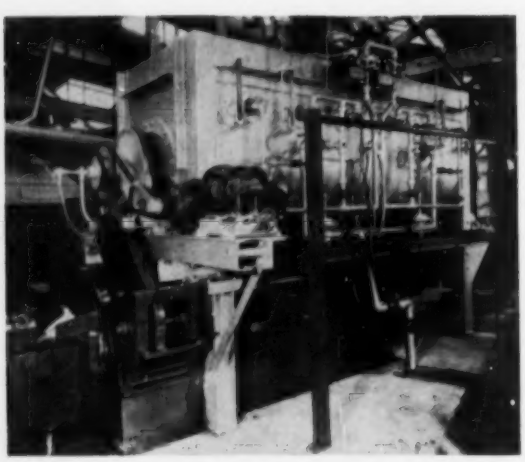

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Blast Furnace . . .

sinter burden when smelting lean ores are greatly emphasized by this paper. No such striking benefits have been noted on tests run on rich ore sinter but there is little published as yet on the results to be gained by the use of a 100% sinter burden of rich ore (over 50% Fe). We may find out in the next few years when large tonnages of 60% Fe taconite pellets or sinter become available.

The British authors conclude from these test results that, as soon as necessary new equipment such as new blowers and sintering machines is installed, it will be possible to operate all of the blast furnaces at this plant on nearly 100% sinter burden with greatly lower costs and a much higher output.

E. C. WRIGHT

Effect of Temperature on Titanium Alloys

Digest of "Tensile Properties of Some Titanium Alpha Solid Solutions up to 600° C", by J. W. Suiter, *Journal* of the Institute of Metals, Vol. 83, May 1955, p. 460-464.

THE instability of the beta phase in binary titanium alloys may cause accelerated creep at moderate temperatures or excessive embrittlement at room temperature. Since the temperatures at which the creep occurs are in the range of greatest potential utility of titanium alloys, a number of single-phase alpha solid solution alloys have been developed.

Two classes of alloying additions have been studied: (*a*) elements which form interstitial solid solutions (oxygen, nitrogen and carbon); and (*b*) elements which form substitutional solid solutions (aluminum, zirconium and tin). With the exception of carbon, all these elements have appreciable solid solubility in alpha titanium.

Base titanium metal used in the experiments was produced by the Kroll process. Metallic alloying additions were made from high-purity aluminum, high-purity tin and Kroll zirconium (99.3% Zr + Hf). Pigment-grade titanium dioxide, gaseous nitrogen and high-purity car-

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Titanium . . .

bon were added to form the other alloys tested.

Ingots were swaged in the range 1290 to 1470° F. to form bars ¾ in. diameter. From this rod, small specimens with a gage length of ¾ in. and a diameter of ¾ in. were turned in a lathe. Before testing, all specimens were annealed for 3 hr. at 1380° F. in vacuum at a pressure of 10^{-5} mm of mercury. After this treatment all alloys showed a uniform structure consisting entirely of alpha solid solution with grain size in the range 1000 to 2500 grains per sq. mm.

Examination of curves for ultimate tensile stress and elongation-to-fracture as a function of temperature for the interstitial alloys showed strikingly the small hardening effect of nitrogen at high temperatures compared with that at room temperature. For example, the alloy with 1.6% nitrogen showed ultimate tensile at room temperature about 50,000 psi. greater than that of the 0.2% nitrogen alloy, but at 1110° F. the difference was reduced to about 4000 psi.

In general, the tensile-temperature curves for all the alloys studied could be divided into three categories, as follows:

1. Up to 570° F. the strength dropped rapidly, a decrease more marked for interstitial than for the substitutional solid solutions.
2. In the range 570 to 930° F. the strength was almost independent of temperature.
3. Above 930° F. the strength again fell rapidly.

Two conclusions can be reached from the practical viewpoint. First, it would appear beneficial to remove impurities and to induce hardening by other means less dependent upon temperature. Second, it might be possible to make alloying additions which would decrease the freedom of movement of interstitial atoms and so delay to higher temperatures the final decrease in strength.

At the moment there is no indication as to what additions would bring this about.

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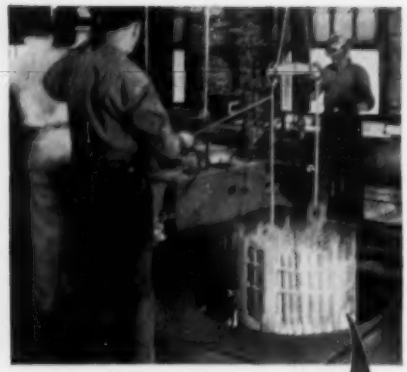

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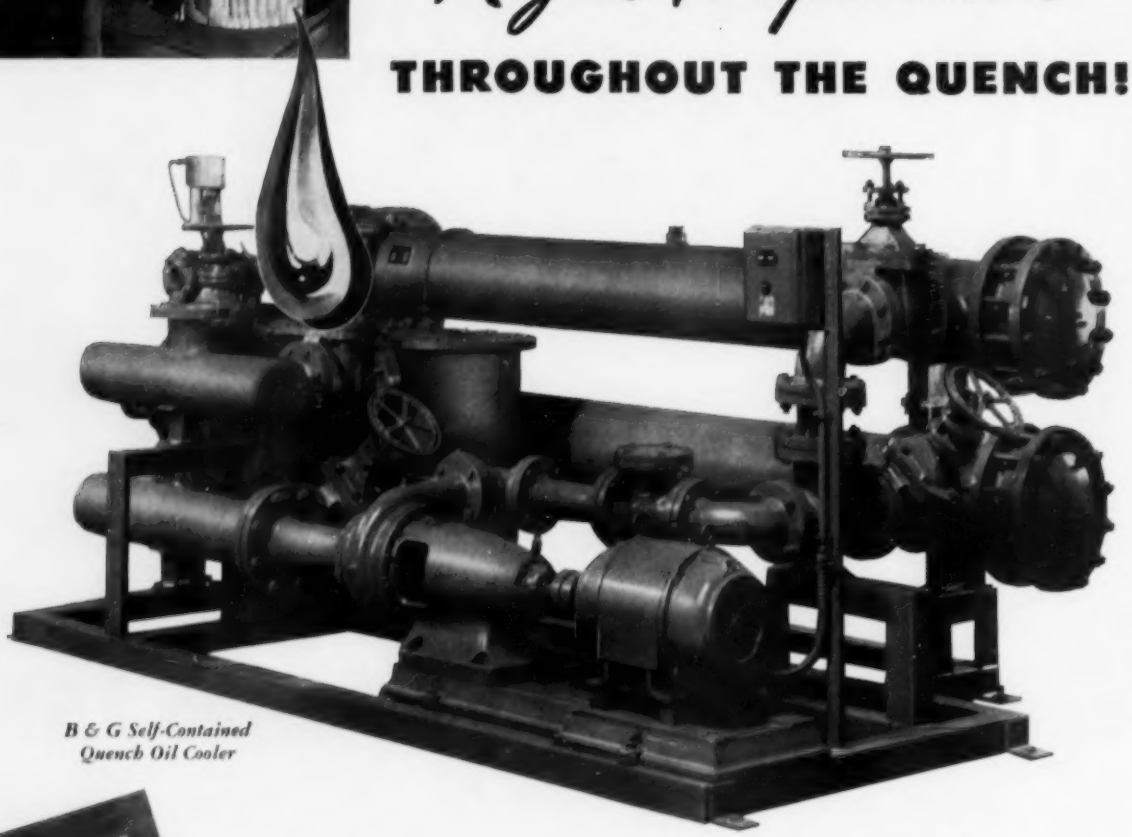

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Differences in the structure of ordinary chromium and Crack-Free Chromium deposits are shown by the photomicrographs below.

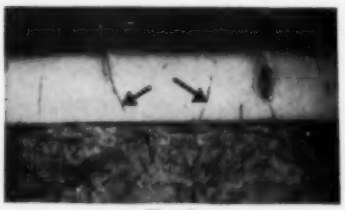

Fig. 1

Fig. 2

Figure 1 shows a cross section of etched ordinary chromium .00125" thick, with part of its network of cracks. Note that some cracks extend through the deposit to the base metal, providing an unimpeded path for corrosives.

Figure 2 shows a section of etched Crack-Free Chromium also .00125" thick. Note the complete absence of cracks.

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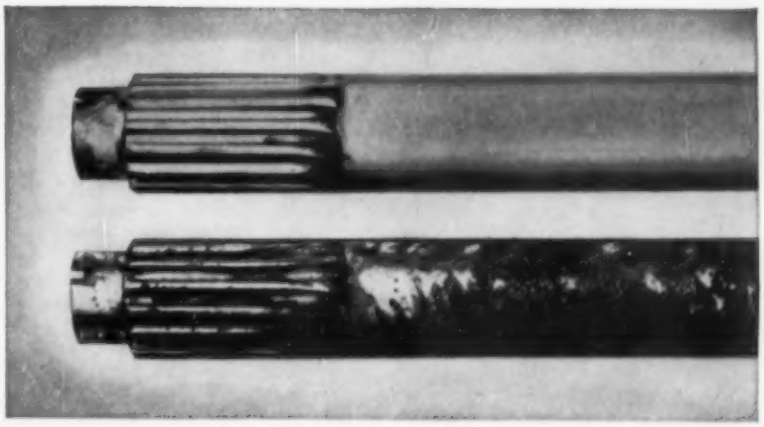

Upper steel shaft, with 0.0005 inch of Crack-Free Chromium, was virtually unaffected after 100-hour salt spray test. Surface of lower shaft with 0.0005 inch of ordinary chromium was completely covered with rust.

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Unichrome Crack-Free Chromium Plating produces more ductile deposits which are free from cracks. Deposits do not crack even when they are built up to hard plating thicknesses. In this respect they are unlike ordinary chromium which develops cracks, providing corrosives with paths to the underlying metal.

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The photograph above shows that .0005" of Crack-Free Chromium plated directly on the steel prevented rusting of shafts subjected to 100 hours of salt spray, while the same thickness of ordinary chromium failed completely.

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For many decorative applications, Unichrome Crack-Free Chromium can be plated directly on steel or zinc base die castings, eliminating need for scarce nickel.

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Crack-Free Chromium deposits are hard (500 to 700 Knoop), have a low coefficient of friction, and a non-galling, non-seizing surface. The plate has superior ductility and resistance to thermal shock. Unusual leveling action is provided by the solution.

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Unichrome Crack-Free Chromium has already proved its advantages for hard chromium plating and certain decorative applications in successful commercial operations. Bulletin CFC-1 gives more details. Send for your copy.

16

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right: Warped into the cable dock at Western Electric's Point Breeze Works are the loaded barges ready to carry the big submarine cable to the site of its installation.

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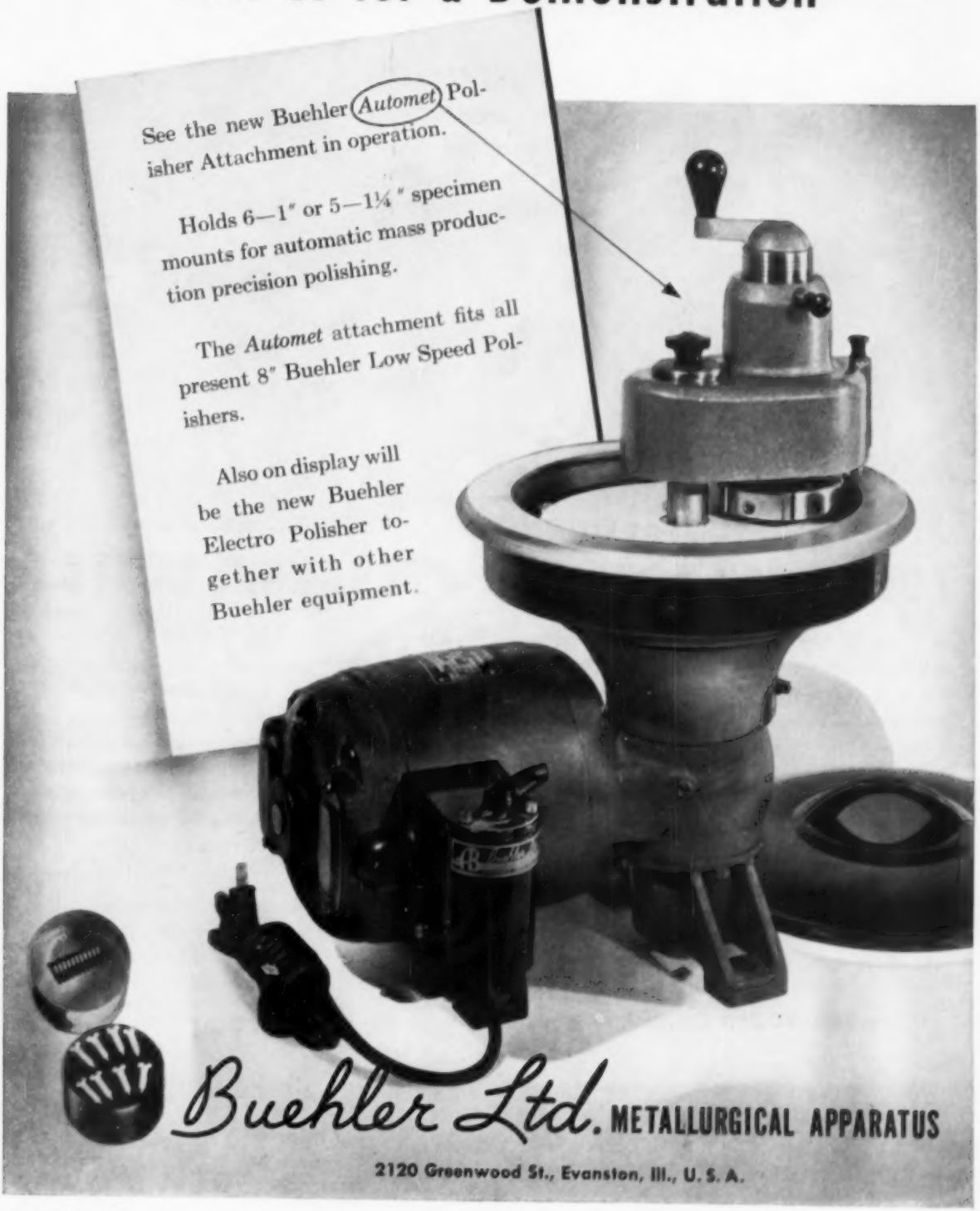
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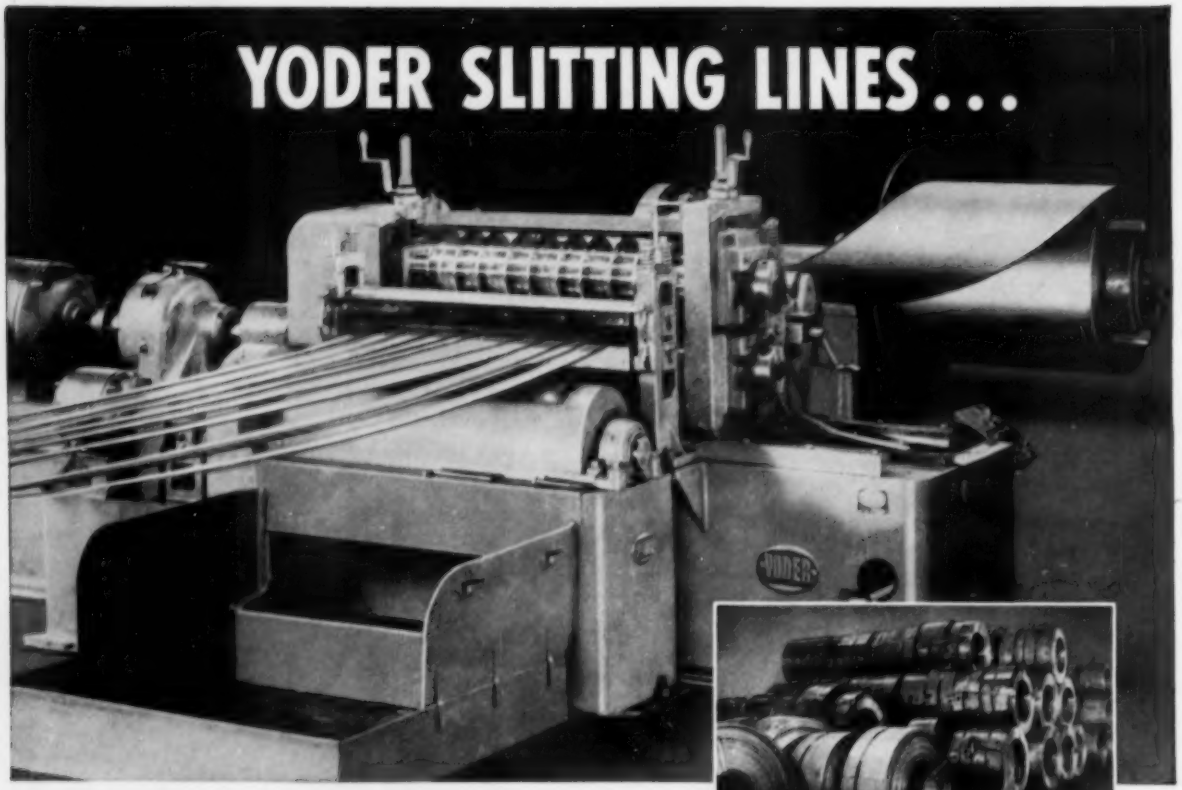

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A relatively small, low-cost Yoder slitting line offers attractive savings possibilities and high production in slitting small and medium coil sizes and strip gauges. Yoder has standardized a series of such machines, affording a rare combination of low cost and productive capacity amply sufficient for the needs of the great majority of sheet metal fabricators and custom slitting shops. Supplementing the standardized series are *special models for slitting big coils and heavy gauges at high speeds.*

For requirements as low as 100 tons per month, one of the standardized Yoder slitting lines will pay for itself in short order. The savings PER TON increase rapidly with decrease in coil size and width of strands to be slit.

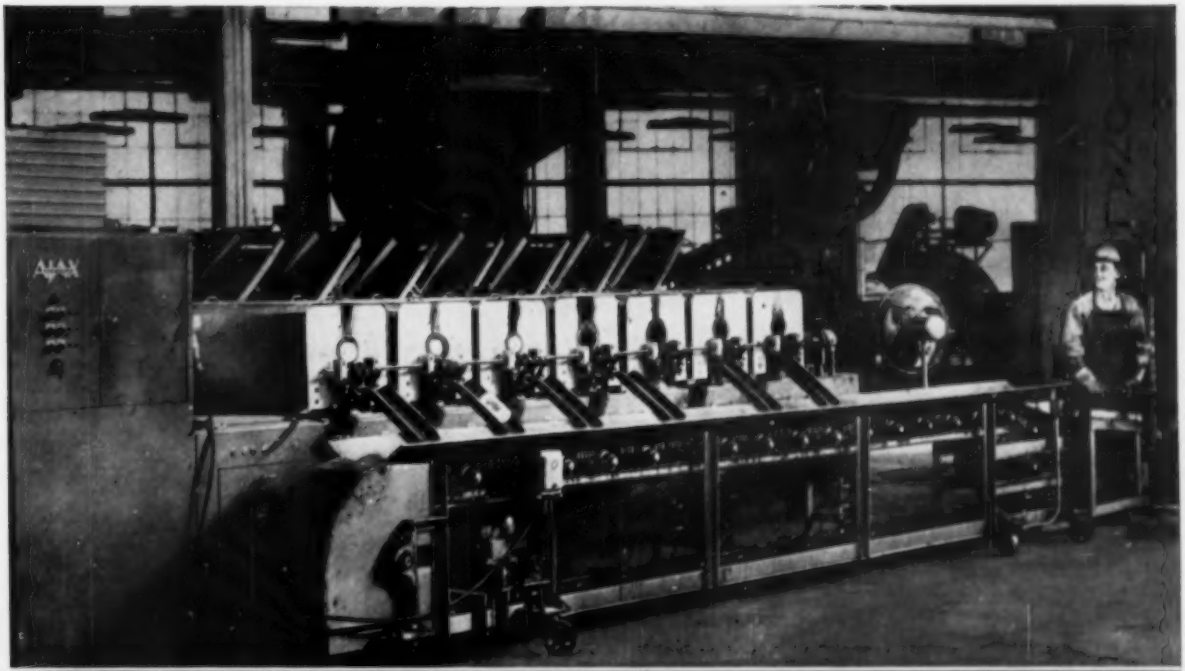
Another important advantage gained by fabricators having their own slitter is the ability, from a relatively small stock of standard width coils, to meet expected and unexpected needs for slit strands in a few hours. This means easier production planning and greatly reduced strip inventories, in addition to lower prices and quicker deliveries of their strip purchases.

Yoder Slitter Book contains basic information on the economics and mechanics of slitter operation, with time and cost studies, production records and other valuable data. Send for it.

THE YODER COMPANY • 5595 Walworth Ave. • Cleveland 2, Ohio

ENGINEERING YODER MANUFACTURING

ROTARY SLITTING LINES
COLD ROLL FORMING MACHINES
ELECTRIC-WELD PIPE AND TUBE MILLS



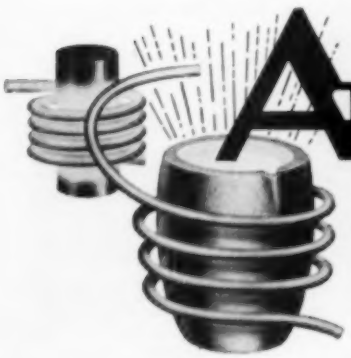
want to mechanize forging?

This large forge shop could show you how. Turning out auto and tractor gears along with hundreds of other parts large and small, it relies upon Ajax induction heating for faster, more efficient production . . . lower material cost . . . greatly reduced manpower . . . and an impressively low reject average.

A complete battery of over a hundred Ajax-Northrup heaters can be put into service here for heating bars of various lengths and weights and in sizes from one inch rounds to four inch squares, each scheduled for automatic or even patterned heating at just the desired rate for the forging operation. Rapid induction heating makes scale formation almost nonexistent; forging dies last much longer.

Here is mechanization brought to the difficult forging process—thanks to the speed, precision, and reproducibility of Ajax-Northrup heating. An Ajax representative will be glad to show you how it can help mechanize your production. Or, just write Ajax Electrothermic Corporation, Trenton 5, New Jersey, for Bulletin 27-B.

Associated Companies: Ajax Electric Company—Ajax Electric Furnace Co.—Ajax Engineering Corp.



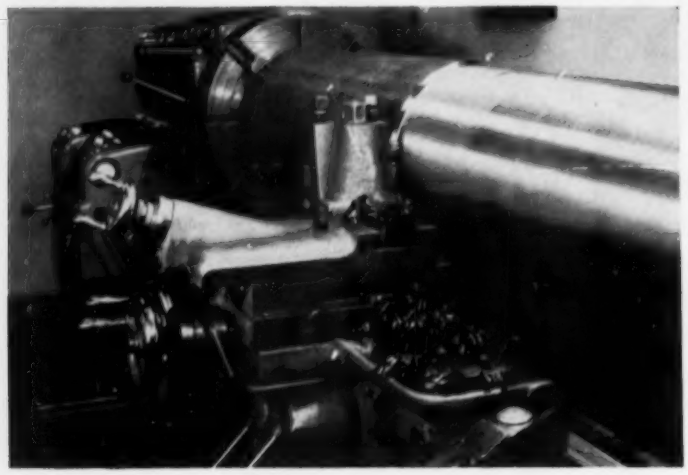
AJAX NORTHRUP *SINCE 1916*

INDUCTION HEATING-MELTING

NEW...ALL NEW!

FIRTHITE TXH

A heavy-duty, general purpose premium Carbide at no premium price



OUTSTANDING FEATURES OF TXH

- Higher hardness to strength ratio.
- Improved impact resistance.
- Wider range of applications.
- Cooler operating temperatures.
- Higher edge strength.
- Greater resistance to abrasion.

TXH is new, brand new, not just another grade designation for an altered existing grade. It is a completely new concept . . . a combination of materials and processes designed specifically to do heavy duty, high production cutting operations better than they have ever been done before. It does.

During development in Firth Sterling laboratories, FIRTHITE TXH *out-performed* and *outlasted* all other *premium grades of carbide.* After thorough introduction in the field, performance has exceeded laboratory predictions in case after case.

Here is a premium quality carbide developed for an age of automation which, at no extra cost, out-performs and outlasts all others.

Available from stock now in all standard tips and tools. Try it *now* and *prove it yourself!*

FOR ENGINEERING SERVICE CALL YOUR NEAREST FIRTH STERLING REPRESENTATIVE

R 3/4

Firth Sterling

—INC—

GENERAL OFFICES: 3113 FORBES ST., PITTSBURGH 30, PA.

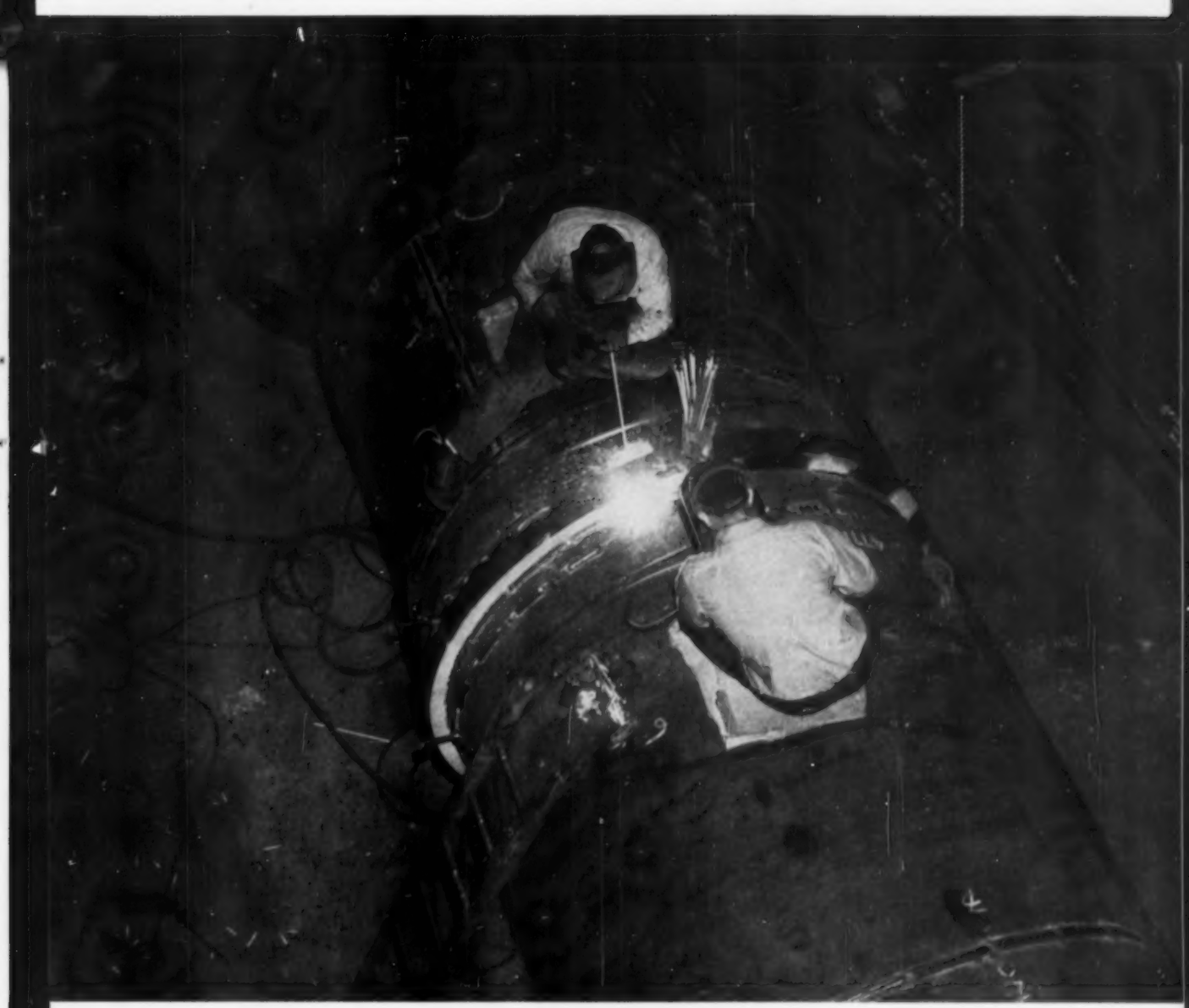
MILLS: McKEESPORT, TRAFFORD, DETROIT, HOUSTON

OFFICES AND WAREHOUSES*: BIRMINGHAM CHICAGO* CLEVELAND DAYTON DETROIT* HARTFORD* HOUSTON LOS ANGELES* NEW YORK PHILADELPHIA PITTSBURGH WASHINGTON WESTFIELD, N.J.

PRODUCTS OF FIRTH STERLING METALLURGY

High Speed Steels
Tool & Die Steels
Stainless Specialties
High Temperature Alloys
Sintered Tungsten Carbides
Firth Heavy Metal
Chromium Carbides
High Temperature Cermets
Zirconium

CALL YOUR FIRTH STERLING DISTRICT OFFICE OR DISTRIBUTOR. ASK MR. TOOLEY.



Here's how one manufacturer saves 20% on over-all manufacturing costs with SSW forged rings

By switching to Standard Steel forged steel rings a leading manufacturer of asphalt drying units saves 20% on over-all manufacturing costs. Used as rails on which 25-ft. long dryer drums rotate, these solid rings have replaced hot rolled steel bars which were formed into hoops and welded. It was found that these bars cracked under the severe load and pressure of the drums turning at 8 to 10 rpm.

Thanks to Standard Steel's high ductility and inherent uniform physical properties this problem no longer exists. The careful heat treating and tempering processes applied to these rings makes them highly resistant to impact . . . gives them longer-lasting life and better performance in heavy-duty operations.

Follow the lead of other manufacturers and fabricators by improving your product and cutting costs with Standard Steel forgings. You'll profit by sending the coupon today for our new folder on forged weldless rings and flanges.

Standard Steel Works Division

BALDWIN-LIMA-HAMILTON

Dept. 8924, Standard Steel Works Division
Baldwin-Lima-Hamilton Corporation, Burnham, Pa.

Please send me Bulletin No. 10,000, "How Forged Weldless Rings and Flanges Improve Your Product and Cut Your Costs."

Name _____ Title _____

Company _____

Address _____

City _____ Zone _____ State _____

How Do Lightweight Refractories Cut Fuel Costs And Boost Furnace Output?

Here, certainly, is a timely question. There's a heavy squeeze today on most furnace operators for lower costs, larger production . . . or both. And despite all the economies they've put into effect so far, they're still searching hard for ways to make their furnace dollars do a bigger job.

The following discussion brings out a number of facts, often overlooked, about the money-saving, profit-building potentials inherent in *lightweight* insulating firebrick.

Q. First of all, just what do you mean by "lightweight" insulating firebrick?

A. Compared with dense, fireclay brick weighing approximately 7½ to 8½ pounds each, insulating firebrick range from about 3½ pounds down to slightly over 1 pound for various temperature requirements.

Q. What does this light weight have to do with lower production costs?

A. Briefly, heavy furnace linings waste your fuel dollars two ways:

They soak up and store large quantities of heat which are lost when the furnace is cooled; and they conduct and lose too much heat through the wall.

Lightweight insulating firebrick, on the other hand, contain millions of tiny air cells, heat up and cool quickly, absorbing and storing very little heat. Also, they resist heat flow, keeping it inside the furnace to do productive work.

Q. I can see why you would save on fuel — but how much?

A. There's no single answer to that question — there are too many variables to be considered. But to give you an idea of these savings, here are a few actual examples:

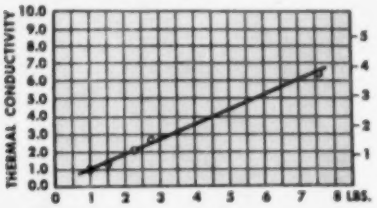
The operator of a large forge furnace cut his fuel costs more than 50% after changing to *lightweight* insulating firebrick.

A manufacturer of electric kilns states that insulating firebrick result in heat savings of fully 25%.

A magnesium melting crucible furnace that formerly used 1,000,000 BTU's per hour now does the same job with 500,000 BTU's, thanks to insulating firebrick.

Q. Increased production has also been pointed out as an advantage of insulating firebrick. How do you explain this?

A. Again the answer lies in lightness of weight. Because lightweight firebrick store and conduct less heat, they come up to operating temperature faster — cool down faster, too. This means — shorter heating cycles.



Relation between weight and thermal conductivity for several brands of kaolin base refractories. (mean temperature, 900F)

Secondly, because lightweight firebrick conduct far less heat than heavy, dense firebrick, you don't have to build as thick a wall. This gives you more hearth area per square foot of floor space.

Thirdly, lightweight firebrick respond more rapidly to changes in furnace heat input, which means closer temperature control and fewer rejects in many instances.

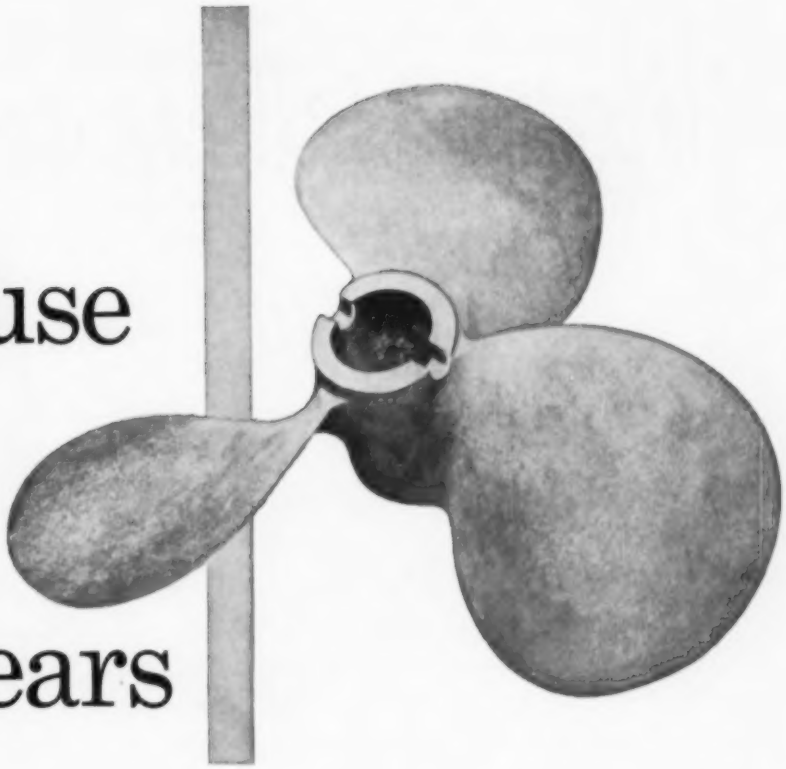
It's just like adding extra furnace capacity without adding to your furnace investment.

Q. Are there any differences in the performance of the various brands of insulating firebrick available?

A. Naturally, the *lighter* the brick the greater the fuel savings and furnace output. And the lightest insulating firebrick of all, for any temperature range — if you'll pardon our mentioning it — are B&W Insulating Firebrick.

THE BABCOCK & WILCOX CO.
Refractories Division
General Offices:
161 East 42nd St., New York 17, N. Y.
Works: Augusta, Ga. R-309

Still in use after 4 years



in hot sulphuric acid and chlorides

PROBLEM.... Agitator propellors were failing at a rate of one every three months in dye kettles where hot sulphuric acid was mixed with chlorine-bearing organic chemicals. Sometimes corrosion was so severe that the propellors fell off the shaft and chipped the kettle lining. This required a major overhaul.

REMEDY..... Agitator shaft and propellor made of HASTELLOY alloy D were installed.

RESULT..... Four years later the same propellor and shaft made of HASTELLOY alloy D are still in service.

HASTELLOY alloy D has excellent resistance to sulphuric acid in all concentrations and at temperatures up to the boiling point. In addition, it is resistant to many other acids and salts frequently used in solution with sulphuric acid. For a copy of a booklet describing HASTELLOY alloys, get in touch with the nearest Haynes Stellite Company office.

HAYNES TRADE-MARK ALLOYS

HAYNES STELLITE COMPANY

A Division of Union Carbide and Carbon Corporation

UCC

General Offices and Works, Kokomo, Indiana

Sales Offices

Chicago · Cleveland · Detroit · Houston · Los Angeles · New York · San Francisco · Tulsa

"Haynes" and "Hastelloy" are registered trade-marks of Union Carbide and Carbon Corporation.

We have just one point to make—

When it comes to **ELECTROPLATING** and allied operations, one name means most to the men who buy . . . **H-VW-M** . . . the manufacturer who supplies every major requirement in processes, equipment and supplies.

Single source? . . . Yes, and what's more important—single responsibility.

PLATEMANSHIP is H-VW-M's unique combination of: the most modern and complete laboratory for testing and development . . . the ability to provide complete equipment and supplies for every plating and polishing need . . . the complete background of knowledge and experience in every aspect of plating, polishing, cleaning and anodizing.

H-VW-M

HANSON–VAN WINKLE–MUNNING COMPANY, MATAWAN, NEW JERSEY

PLANTS: MATAWAN, NEW JERSEY • GRAND RAPIDS, MICHIGAN

SALES OFFICES: ANDERSON (IND.) • BALTIMORE • BELOIT (WISC.) • BOSTON • BRIDGEPORT • CHICAGO • CLEVELAND DAYTON • DETROIT • GRAND RAPIDS • LOS ANGELES • LOUISVILLE • MATAWAN • MILWAUKEE • NEW YORK PHILADELPHIA • PITTSBURGH • PLAINFIELD (N. J.) • ROCHESTER • ST LOUIS • SAN FRANCISCO • SPRINGFIELD (MASS.) UTICA • WALLINGFORD (CONN.)

INDUSTRY'S WORKSHOP FOR THE FINEST IN PLATING AND POLISHING PROCESSES · EQUIPMENT · SUPPLIES

XIII

This is the thirteenth of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.

Manganese in Alloy Steels

A common and economical alloying agent, manganese is both highly respected and highly essential. It is one of the most basic elements in alloy and carbon steels; in fact, all analyses contain manganese to some extent. Whenever the content exceeds 1.65 pct, manganese steels are classed as alloy steels.

Manganese is one of the energetic deoxidizers, and has less tendency to segregate within the ingot than most other common elements. It is quite beneficial to surface quality in all carbon ranges and minimizes "red shortness" or susceptibility to tearing and cracking at rolling temperatures.

Manganese contributes markedly to strength and hardness, but to a lesser degree than carbon. Actually, the effectiveness of manganese in this respect depends largely upon the carbon content, for higher-carbon steels are more affected by manganese than are the lower-carbon steels.

Another function of manganese is to decrease the minimum — or critical — cooling rate. In this connection it enhances the hardenability. As might be expected, high manganese content with increasing carbon has a tendency to lower ductility and weldability.

Fine-grained manganese steels attain unusual toughness and strength. Such steels are often used in the making of gears, spline shafts, automobile axles, steam valves, rifle barrels, cylinders for compressed gas, and many other products. With a moderate amount of vanadium added, manganese alloy steels are also used for forgings too large to be liquid-quenched properly.

As mentioned earlier, manganese is one of the most fundamental constituents of steel. If you would care to know more about its properties, applications, and effects in alloy combinations, Bethlehem technicians will be glad to work closely with you. The same holds true, of course, when your problem involves other elements of alloy steel.

And when you require new supplies of steel, remember that Bethlehem manufactures the entire range of AISI standard alloy grades, as well as special-analysis steels and all carbon grades. You can place complete confidence in their quality.

If you would like to have a reprint of this advertisement, or of the entire series from I through XIII, please write to us, addressing your request to Publications Dept., Bethlehem Steel Company, Bethlehem, Pa.

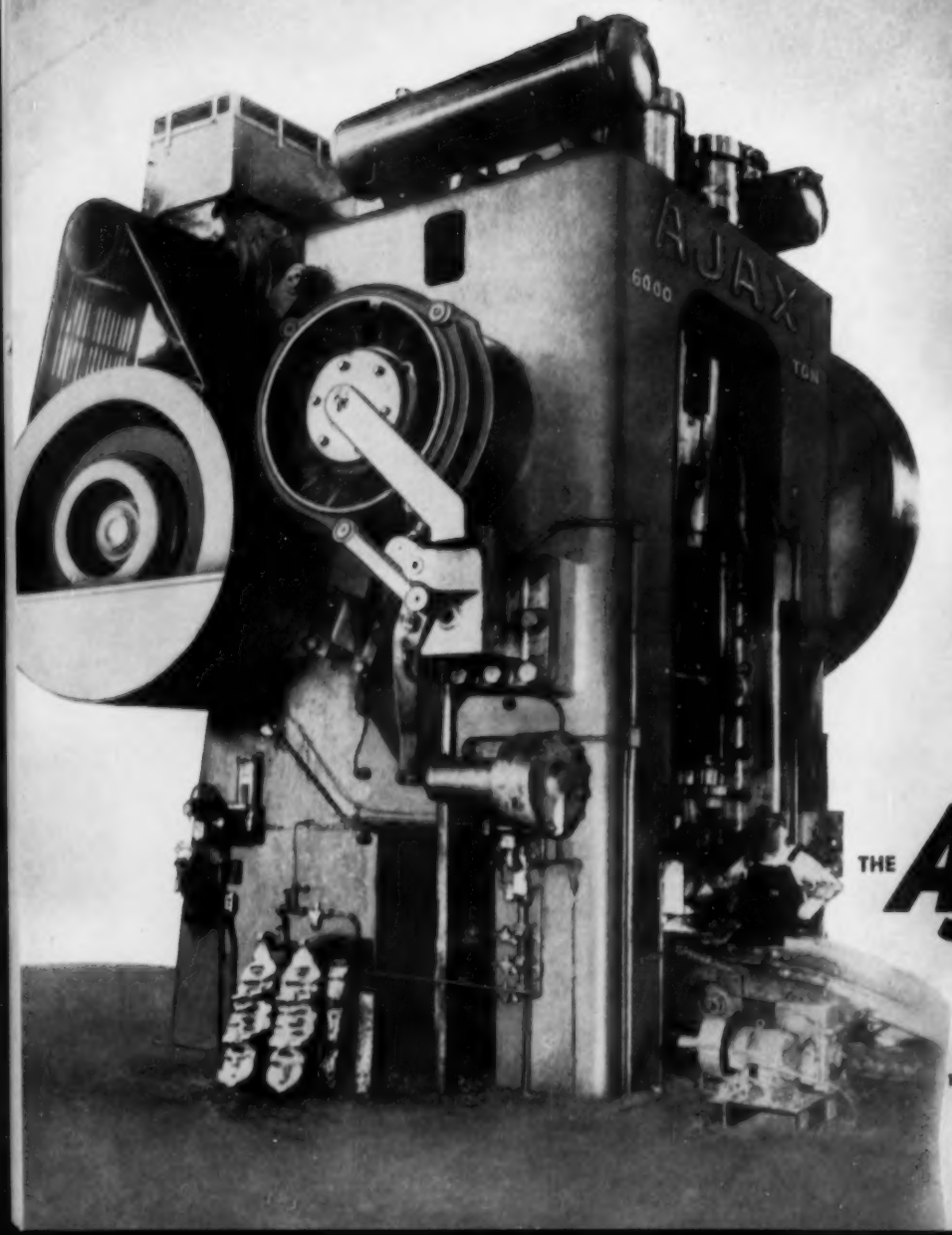
BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. *Export Distributor:* Bethlehem Steel Export Corporation

BETHLEHEM STEEL

BETHLEHEM STEEL

High Production of Automobile Crankshaft Forgings on AJAX *High Speed* Forging Presses



Production More than Doubled Over Former Methods on 6000 Ton Ajax Forging Presses

Crankshafts With Less Draft on Counterweights for Lower Machining Costs

For Your Forging Needs . . . Ajax Forging Presses Sizes 300 Ton to 8000 Ton

THE **Ajax** MANUFACTURING COMPANY

CLEVELAND 17, OHIO

110 S. DEARBORN ST., CHICAGO, ILL.

W. P. WOOLDRIDGE CO.

1209 BURLINGAME AVE., BURLINGAME, CAL.
6440 FLEET ST., LOS ANGELES 22, CAL.

Write for Bulletin 75 C

Some Notes About Authors

Herbert A. Trenkler

The senior author of our leading article in *Metal Progress's* fourth annual review of international progress in metallurgy, Dr. Mont. Dipl. Ing. Herbert A. Trenkler is managing director of the metallurgical section of VOEST (United Austrian Iron & Steel Works). After graduation from the technical colleges at Munich and at Leoben, Austria, he became successively engineer in the research department of the Dillingen steel plant in the Saar, assistant manager at Oberhausen in the Ruhr, and steel plant manager at Hagondange, Lorraine, before joining the organization at Linz, Austria, in 1948.

H. F. Hauttmann

Dr. H. F. Hauttmann, co-author with Dr. Trenkler, was also educated at Munich and at Leoben, and joined the staff of Gutehoffnungshutte in Oberhausen, Ruhr, Germany in 1921, becoming manager of research. In that position he assisted in the study of oxygen refining of pig iron carried out by Lellep. Since 1948 he has managed the research department of VOEST at the Linz plant. One of his special interests is the production of structural steels resistant to the propagation of cleavage fracture. He has also been visiting lecturer at the Metallurgical College at Leoben, Austria, since 1950.

Henry H. Hausner

A leading American authority on powder metallurgy, Henry Hausner has contributed to *Metal Progress* on frequent occasions. Immigrating to America in 1940 from his native Vienna, he joined the staff of Sylvania Electric Products, and became manager of engineering of the firm's atomic energy division in 1952. Late in 1955 he became general manager, Nuclear Engineering Div., Penn-Texas Corp., New York. Hausner finds time also to serve as adjunct professor at Brooklyn Polytechnic Institute. He was general chairman of the symposium on powder metallurgy at the Metal Congress in Philadelphia last October, and is editing a comprehensive book on "Powder Metallurgy in Atomic Energy."

Takashi Kimura

Takashi Kimura, co-author of the article on p. 61 on "Powder Metallurgy in Japan" is with the Japanese Telephone Co. of Tokyo, and is studying in America on a Fullbright Fellowship.

Jean A. Delcroix

Jean A. Delcroix was born in Paris in 1921 and in due course passed the entrance examinations and was admitted for study in the Ecole Centrale, completing his courses and obtaining the degree of Ingenieur des Arts et Manufactures in 1943. When World War II was ended he worked for a colliery for a few months, but then joined the Persan plant of CIEPM (Comptoir Industriel d'Etirage & Profilage de Metaux) where the Ugine-Séjournet extrusion process was under active development. He is well qualified on this matter, since he has been manager of operations there since 1948.

Werner A. Stauffer

Escher Wyss Engineering Works is a very large machinery works completely surrounded by the city of Zurich, and with beautiful office and engineering buildings facing (appropriately enough) Escher Wyss Platz. Its production of heavy machinery—especially for power plants—is modern and large by anybody's standards.

Watching over the materials of construction for the last 20 years has been Werner A. Stauffer, chief metallurgist and head of the test department, author of the article on "Wear of Metals by Sand Erosion" (p. 102). Since 1944 Mr. Stauffer has acted as chairman of the Swiss Standardizing Committee for Aircraft, and has also directed the Standardizing Committee for the Assoc. of Swiss Machinery Manufacturers.

Herwart Opitz

The senior author of the article "Heat Treatment of Steel for Good Machinability" (p. 108) was chosen at a luncheon meeting of metallurgists during the Dusseldorf sessions of the Joint Metallurgical Societies Meeting in Europe last year as the foremost German authority on machinability of metals. He has been a close student of this matter during the years since 1936 when he started teaching at the Technical University at Aachen. He believes that machinability, as measured by the wear on the tool, is directly related to the shear strength of the steel being cut, and hence can be predicted by a simple physical test.

J. C. Chaston

Dr. J. C. Chaston has been in charge of metallurgical research for Johnson, Matthey & Co. (which to Britishers means platinum and other precious metals) since 1938—in fact manager of the research laboratories since 1953. He has his degree from the Royal School of Mines in London. From 1925 to 1936 he worked with powdered magnetic materials and with lead and lead alloys for Standard Telephones & Cables. Then for two years he was senior lecturer in metallurgy at the Royal Technical College in Glasgow. Thus, it is easy to see why Dr. Chaston was chosen to head the conference on metals of high purity (the subject of his paper on p. 64) during the Joint Metallurgical Societies Meeting in Europe in the early summer of 1955. It was one of the most successful meetings of the entire program.

N. H. Polakowski

A graduate Mechanical Engineer from the University of Lwow, Poland, in 1938, Polakowski worked in his native country on problems connected with the plastic working of metals and mechanical metallurgy, receiving in 1950 the Andrew Carnegie Silver Medal from the British Iron & Steel Institute for his contributions to technology in those fields. He was impressed by the Russian Government for two years' service with its Commissariat of Ferrous Metallurgy. Immigrating to Great Britain in 1948, he studied and taught at the University College in Swansea, Wales, receiving a doctorate in metallurgy from that institution in 1952. He has always been a close student of the available technical literature in Polish and Russian, as well as in the English language. He now lives in Chicago and divides his time between Illinois Institute of Technology and LaSalle Steel Co.

Gerald X. Diamond

Gerald Diamond is a New Yorker by birth but a Cincinnatian by education, graduating as Metallurgical Engineer at the University right in the middle of World War II. After short hitches in the Army and Air Force he came back to his home city and joined Metcut Research Associates. Late in 1954 he was awarded (much to his surprise, he writes) the Buenos Aires Convention Fellowship for study of the metals industries in Colombia. His interesting account of some of his impressions in this South American land is printed on p. 97.

If "Curiosity Killed A Cat" Why Not Mice?

"When a man builds a better mouse trap the ~~world~~ *mice* will beat a path to ~~his~~ *its* door"

For the third time, in thirty-seven years, we present "A Better Mouse-trap" to M. P. readers. Automation has reached the mouse-trap industry! The "ball-bearing mouse-traps", are obsolete! Less cats=more birds. G. A. Engineers, and our ENGINEERED FABRICATIONS Department, to a man, salutes Mr. A. E. Kneff, Inventor of the WORLD'S BEST MOUSE-TRAP!

Frankly, this unique blast of 22 Karet I. Q. among the tin-knockers, and wire benders had us worried. We've made a deal. G. A. won't cast any mouse-traps, as long as Mr. Kneff won't fabricate alloys.

This is no gag. This **psychological,** fully automatic, **repeating** trap uses *NO BAIT.* For *NOTHING,* you get **mice!,** up to twelve at a time! MONEY BACK GUARANTEE. It doesn't kill 'em, just **spanks** 'em into the hopper. Dump the hopper into the "John" and mourn your mice.

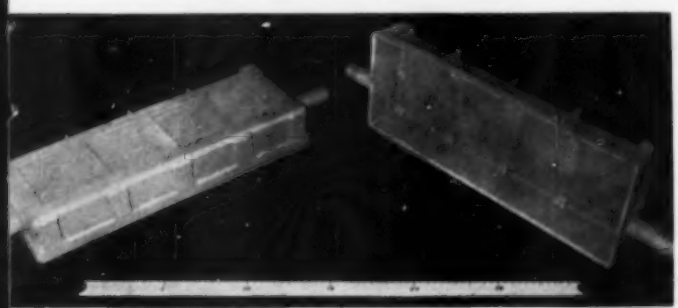
Mr. Kneff, began at the **beginning.** He thoroughly studied the "material" to be processed, drew up a flow-sheet, and proceeded to eliminate 1. Bait, 2. Damage in process, 3. Set-up time and labor, 4. Hazards to operators and others, 5. Splatter and spoilage, 6. Air pollution, 7. Corrosion, 8. Maintenance, 9. MICE! 10. Competition.

Kneff's product, like G. A. Products, is sold on the basis of *SERVICE RENDERED,* and *unit-cost of material processed.* The most important ingredient is BRAINS-BETWEEN-THE-EARS-BEHIND-THE-LEAD-PENCIL. The Kneff trap will not appeal to price-buyers. Many buyers still subordinate the end to the means. They read the **price addition** rather than the **mouse subtraction.** The mice, at least, will get a break, as will the half-trapped manufacturer of quarter-moused traps. **If he doesn't run out of scrap,** he'll not run out of price-buyers. There's one made every minute, (by the last price-peddler who tags him).

This suggests "the chicken-or-the-egg", hassel, or who-did-what-to-who and who-paid? Considering recent self-induced omissions among alloy foundries, **(whose customers paid for less and less, and got about what they paid for)** one need only look behind the lead-pencil and into the scrap-bin.

Perhaps Mr. Kneff's greatest reward is the recognition accorded his "LOYALTY TO THE VISION OF WORK WELL DONE", by men of like mind and VISION. They, through recognizing **their obligation** to MAKE **SOME** CONTRIBUTION to advance the arts and trades BY WHICH THEY LIVE, perceive such integrity and **acumen** in others. Men who make and use "Better Mouse-Traps" in any field are **known by their** CONTEMPT for MEDIOCRITY. They are great guys to work, live, and hunt with. We know that A. S. M. has it's full share, **and are proud to serve them.**

G. A. Solicits your inquiries for ENGINEERED Heat and Corrosion resistant Alloy HIGH TEMPERATURE TOOLING, and Process equipment, Cast, and Fabricated. The Fabricated Q-Alloy Carbo-Nitriding Baskets shown, are one of many hundreds of G. A. products delivering Superior Service per $ cost.



P.S. The Mouse-Traps are Five Bucks Each. 50% discount to G. A. Customers.

An Additorial by the President of GENERAL ALLOYS COMPANY, 405 West First Street, Boston, Massachusetts.

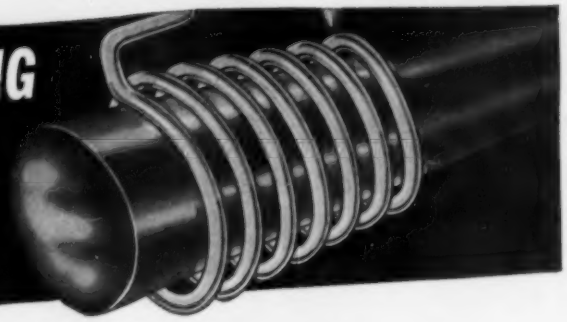
THE FOOTSTEPS OF GENERAL ALLOYS MARK THE PATH OF AN INDUSTRY

YOU CAN HEAT ANYTHING

FROM A NEEDLE . . . TO

A TURBINE SHAFT

FASTER and BETTER



BRAZING

Permits widest choice of silver or copper brazing alloys from lowest to highest melting points. Ideal for brazing carbide tips.

HARDENING

Heat localized exactly where wanted at desired temperature. Ideal for gears, cams, bearing surfaces, cutting tools and other areas that are subject to wear.

SOLDERING

Speedily and neatly performs intricate soldering applications with or without the use of preformed rings.

ANNEALING

Ideal for annealing, stress-relieving, normalizing or preheating selected areas.

MELTING

Readily melts quantities of ferrous and non-ferrous metals in either graphite or ceramic crucibles.

WITH **LepeL**

HIGH FREQUENCY

Induction

HEATING UNITS

The Lepel line of induction heating units represents the most advanced thought in the field of electronics as well as the most practical and efficient source of heat yet developed for industrial heating. With a background of half a century of electrical and metallurgical experience, the name Lepel has become the symbol for quality in induction heating equipment embodying the highest standards of engineering achievement, dependable low cost operation and safety.

If you are interested in the application of induction heating you are invited to send samples of the work with specifications of the operations to be performed. Our engineers will process these samples and return the completed job with full data and recommendations without any cost or obligation.

2½ KW INDUCTION HEATING UNIT

30 KW INDUCTION HEATING UNIT

100 KW INDUCTION HEATING UNIT

LEPEL Electronic Tube GENERATORS
1 KW; 2½ KW; 5 KW; 10 KW; 20 KW; 30 KW; 50 KW; 75 KW; 100 KW.

LEPEL Spark Gap Converters
2 KW; 4 KW; 7½ KW; 15 KW; 30 KW.

All Lepel equipment is certified to comply with the requirements of the Federal Communications Commission.

WRITE FOR THE NEW LEPEL CATALOG . . . 36 illustrated pages packed with valuable information on high frequency induction heating.

LEPEL HIGH FREQUENCY LABORATORIES, INC.
55th STREET and 37th AVENUE, WOODSIDE 77, NEW YORK CITY, N. Y.

U. S. PATENT No. 2,701,712

ORIGINAL "HUMPBACK" FURNACE
C.I. HAYES
U.S. PAT. NO. 2,701,712
OTHER PATS. PENDING

Handles 3 to 5 times as much load

Hayes original Humpback furnace ... with patented features that make it a PRODUCTION furnace.

Hayes patented

Auxiliary Belt Drive

One of three 40-foot Hayes "Humpback" Conveyor Furnaces at Pratt and Whitney Aircraft Division of United Aircraft Corporation. Other prominent users include: RCA, Sylvania, Lansdale Tube, Raytheon, CBS Hytron, Manning-Maxwell-Moore, Westinghouse, General Electric, Aerobraze Corp., Fabriform Metal Products, Commercial Metal Treating Co., Chatham Electronics Corp., Imperial Knife Co., Sonotone.

carries SEVERAL TIMES THE PRODUCTION LOAD of designs that lack this necessary feature.

Copper brazing, stainless bright heat treating, de-gasifying are accomplished with the maximum economy of hydrogen atmosphere in elevated heating chamber of "Certain Curtain" construction ... PLUS production load of 25 lbs. or more per square foot of belt. Visit our laboratory and see it in operation on your work before you buy.

"Better use the BEST!"

Write for literature on "Hayes Humpback" the PRODUCTION Furnace with Auxiliary Drive feature for conveyor copper brazing, bright stainless treatment, de-gasifying and other operations in Hydrogen up to 2100°F.

C. I. HAYES INC. ELECTRIC CERTAIN CURTAIN FURNACES

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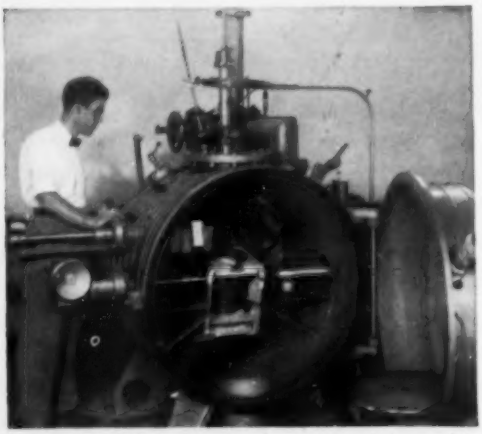
Will Vacuum Melted Metals do for YOUR Product what they do for Jet Planes?

A Vacuum Furnace will help you get the Answer

The roaring gas turbines of 1000 mph jet planes use vacuum melted metal parts to withstand temperatures and stresses that would ruin conventional metal. If you use metal under severe conditions in your product . . . or require "cleaner" metals for smoother surfaces, you should be testing vacuum melted metals today. A high vacuum furnace will help you speed up these tests by supplying your researchers with a ready supply of varying alloys. We have made and operated more high vacuum furnaces than anyone in the world. Can we help you, too? Send coupon below today.



NRC Model 2555 Vacuum Furnaces are now being used by leading aircraft companies, engine manufacturers, investment casters, specialty steel producers to speed up the development of new materials that will meet ever more severe operating requirements.

SALES OFFICES IN PRINCIPAL CITIES

NRC NARESCO EQUIPMENT CORPORATION

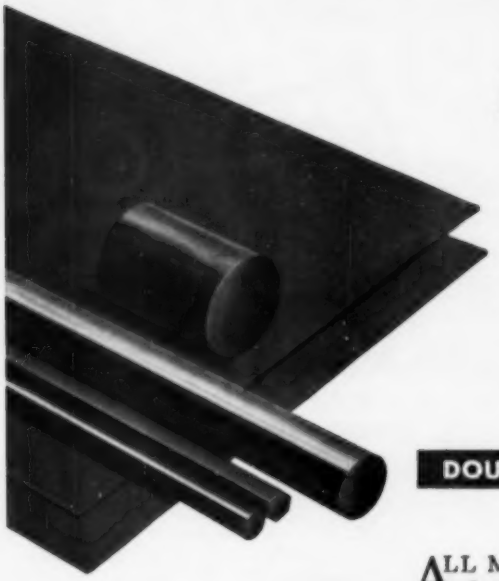
NARESCO EQUIPMENT CORPORATION
Subsidiary of NATIONAL RESEARCH CORPORATION
Dept. 11, Charlemont St., Newton Highlands 61, Mass.

Send me your Vacuum Furnace Bulletin ☐ Have your representative call ☐

Name.....Title.....
Company.....
Address.....
City.....Zone....State.....

TITANIUM

for the full range of mill products call Mallory-Sharon



DOUBLE-MELTED TITANIUM AND TITANIUM ALLOYS

ALL Mallory-Sharon titanium is produced by "Method S" vacuum double melting, resulting in good machineability and forming characteristics. This process eliminates alloy segregation and enables carbon and gaseous contaminants to be held within very low limits. Likewise, Mallory-Sharon's patented rolling method and other technical advances assure you of the highest quality and uniformity.

Call us for the full range of titanium and titanium alloy mill products: rod, bar, sheet, strip, plate, etc. Our technical service group is equipped to give you the latest recommendations on forming, welding, and machining. For complete information write Mallory-Sharon Titanium Corporation, Dept. F-1, Niles, Ohio.

MST GRADE III—This material is commercially pure titanium. It is essentially all alpha titanium and is therefore not hardenable by heat treatment. It is more ductile than any commercial titanium alloy and is weldable. MST Grade III is available as 50,000 psi, 65,000 psi, or 80,000 psi yield strength material.

MST 6Al-4V—A heat-treatable alpha-beta bar and sheet alloy. The Al-V system is of the beta isomorphous type, showing no eutectoid decomposition. This alloy has excellent elevated temperature properties up to approximately 750°F. MST 6Al-4V is relatively insensitive to notches and is weldable.

MST 3Al-5Cr—A heat-treatable alpha-beta bar and forging alloy which is primarily used in the annealed condition. MST 3Al-5Cr has good elevated temperature properties.

MST 4Al-4Mn—A heat-treatable alpha-beta bar and forging alloy which is primarily used in the annealed condition. It has good elevated temperature properties. Eutectoid decomposition is so sluggish that it never occurs in commercial applications.

MST 8 Mn—An alpha-beta sheet alloy used primarily in the annealed condition. It has good formability and may be used at moderately elevated temperatures in the annealed condition. Eutectoid decomposition is so sluggish that it does not occur in commercial applications.

TYPICAL MECHANICAL PROPERTIES

	Form	Ultimate Tensile Strength, psi	Yield Strength, psi	Elongation % in 2"
MST Grade III (Unalloyed) . .	Sheet, Bar	70,000	50,000	25
(3 different strength levels) .	Sheet, Bar	85,000	65,000	23
	Sheet, Bar	100,000	80,000	20
MST 6Al-4V (1)*	Bar	149,000	137,000	13
(2)	Bar	164,000	153,000	13
(3)	Bar	198,000	180,000	9
(4)	Sheet	130,000	120,000	10
MST 3Al-5Cr	Bar	155,000	145,000	13
MST 4Al-4Mn	Bar	150,000	140,000	14
MST 8 Mn	Sheet	140,000	125,000	16

* (1) 1500—½—AC (3) 1700—½—WQ, 900-2-AC
(2) 1400—½—WQ, 1100-8-AC (4) 1450— 2—FC to 1100-AC

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Through Magnaflux Corporation, you have available the broadest range of nondestructive test equipment and materials. From dye penetrant inspection, through every type of magnetic particle and fluorescent penetrant inspection as well as ultrasonic and eddy current inspection methods, you can select the type to meet your needs, exactly.

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Write now for more complete information.

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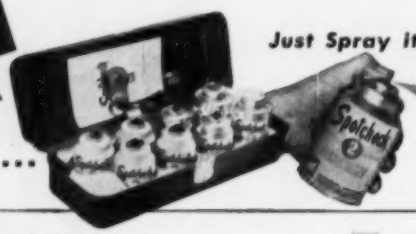
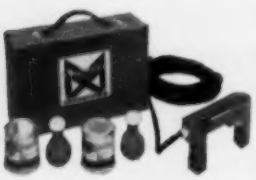


Just Spray It On to Find Cracks

The improved dye penetrant inspection with all materials in pressurized cans . . . A COMPLETE PORTABLE KIT FOR ONLY **$36.00.** (Includes $1.00 for prepaid parcel post—U.S.A. only, local or use tax extra.)

THE MAGNAFLUX Y-5 YOKE KIT



Permits inspection with Magnaflux for surface cracks of all types—quickly and with positive indications. Completely portable; operates from any 115 V. AC outlet, or from a 12-volt car battery. Ideal for off-the-road equipment, or for inspection difficult by other methods.

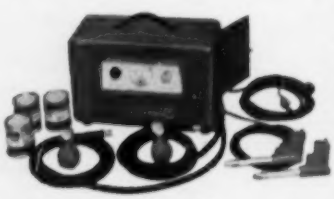
Note: A similar Kit, the Y-M 5 is also available. It contains Alnico permanent magnets, and requires no power source.

MAGNATEST

Eddy Current Electronic Instruments

A broad line of instruments for measuring conductivity, material, hardness . . . evaluating alloy or material—all at production speeds where required.

MAGNAFLUX K-05 UNIT



Portable Magnaflux Kit, 500 ampere output, operates from 110 V. AC. May be used to hand inspect large or small magnetic parts, regardless of shape. Axles, spindles, and machine parts may be inspected without disassembly. Utilizes either Magnaglo or Magnaflux powders. Weighs less than 40 lbs., with cables.

MAGNAFLUX DRC-543 UNIT

Especially designed for low-cost and effective production inspection of parts and tools in high volume. Handles parts up to 54" long. Magnaglo head permits use of the fastest wet alternating current method. Has motor driven 30-point demagnetizing switch and foot control for contact heads.

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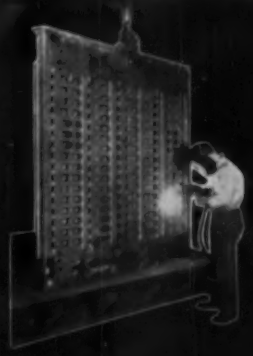

WELDING SOLVES ANOTHER WEIGHT PROBLEM

(and USS "T-1" Steel solves the welding problem!)

Bedplates for modern color-printing presses have to be rugged—but as lightweight as possible. They must withstand constant pounding from printing rollers and cutting knives. And, since they move back and forth continually, they've got to be lightweight for fast, efficient operation. It is a good place to use a welded assembly of steel plate.

But that's where Graver Tank & Manufacturing Co., Inc., ran head-on into a tough fabrication problem. Alloy steel with the necessary strength and durability was difficult to weld. And with 534 welds to make on *every* bedplate, this was a king-size headache.

NO MORE HEADACHE!

Now the headache is gone. Production costs are down. And the finished bedplates are working hard and long . . . taking a tremendous daily pounding without distortion.

The solution? Just a switch to a remarkable *new* alloy steel, USS "T-1" Steel.

"'T-1' Steel is very strong. Very tough. Able to take vicious impact abuse. Yet, it's easy to weld," says Mr. H. McDonald, Superintendent at Graver.

HOW ABOUT YOU?

If you have tough jobs, rugged jobs, where you want to weld your way to lower costs, give this new steel a try. We think you, like Mr. McDonald, will find it the best thing you have ever used. Right now, "T-1" is in service and doing well in bridges, power shovels, steam turbines, electrical transformer tanks, flywheels, pressure vessels, mine cars, and lots of other places. Write for details. United States Steel, Room 5084, Pittsburgh 30, Pa.

"TOP QUALITY" That's how Graver Tank & Manufacturing Co., Inc., East Chicago, Indiana, describes new USS "T-1" Steel. It gives them a yield strength of 90,000 psi . . . exceptional resistance to impact abuse . . . and good weldability. It enables them to build extremely rugged, all-welded bedplates for printing presses.

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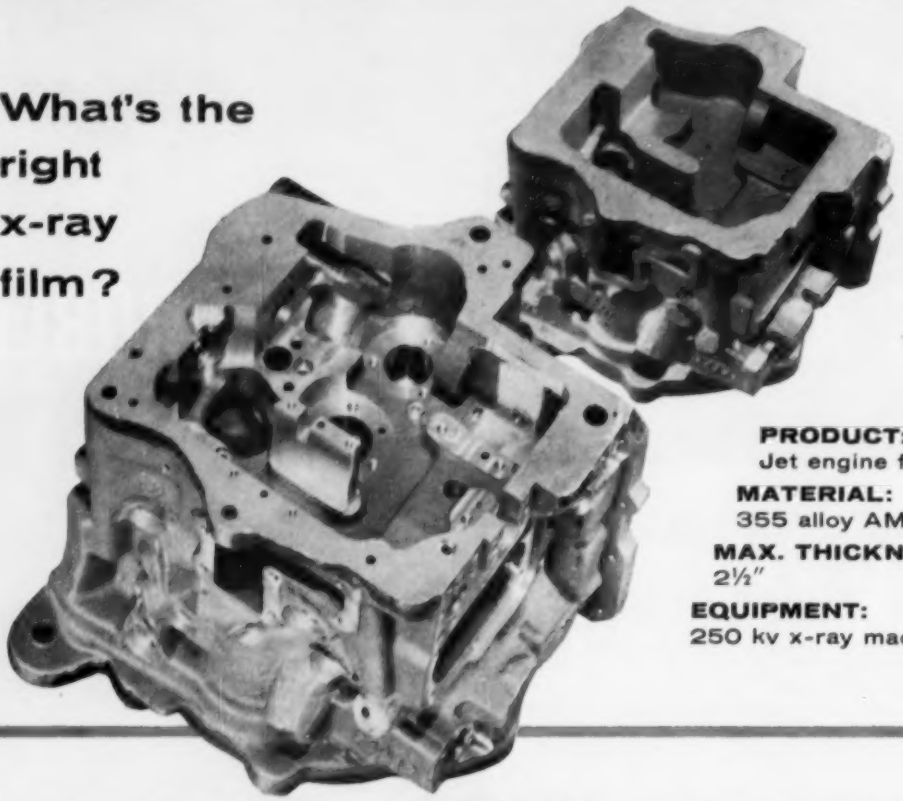
USS "T1" CONSTRUCTIONAL ALLOY STEEL

USS

6-15

UNITED STATES STEEL

What's the right x-ray film?



PRODUCT:
Jet engine fuel pump
MATERIAL:
355 alloy AMS 4214
MAX. THICKNESS:
2½"
EQUIPMENT:
250 kv x-ray machine

✓ Kodak Industrial X-ray Film, Type A

Machining costs 8 times the price of this rough casting. And the alloy used is prone to gas and shrinkage which can make the part a total loss. So radiography is used to insure that only sound castings are machined.

In making these exposures the radiographer used 165 kv, 80 secs at 48 in., and Kodak Industrial X-ray Film, Type A.

This film is first choice for routine examination of light alloys as it provides short exposure time with suitably low kilovoltage technics.

RADIOGRAPHY...
another important example of Photography at Work

THERE'S A RIGHT FILM FOR EVERY PROBLEM

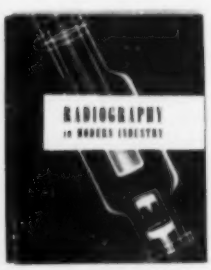
Whatever your radiographic problem, you'll find the best means of solving it in one of Kodak's four types of industrial x-ray film. This choice provides the means to check castings and welds efficiently, offers optimum results with varying alloys, thicknesses, and radiographic sources.

Type A—has high contrast and fine graininess with adequate speed for study of light alloys at low voltage—heavy parts at intermediate and high voltages. Used direct or with lead-foil screens.

Type F—provides the highest available speed and contrast when exposed with calcium tungstate intensifying screens. Has wide latitude with either x-rays or gamma rays when exposed directly or with lead screens.

Type K—has medium contrast with high speed. Designed for gamma ray and x-ray work where highest possible speed is needed with available kilovoltage, without use of calcium tungstate screens.

Type M—provides maximum radiographic sensitivity with direct exposure or lead-foil screens. It has extra-fine grain and, though speed is less than Type A, it is adequate for light alloys at average kilovoltages and preferred for much million- and multimillion-volt work.



RADIOGRAPHY IN MODERN INDUSTRY

A wealth of invaluable data on radiographic principles, practice, and technics. Profusely illustrated with photographs, colorful drawings, diagrams, and charts. Get a copy from your local x-ray dealer—price $3.

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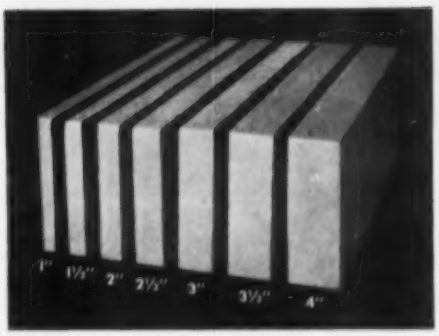
Specify J-M Superex, industry's favorite block insulation

Made from diatomaceous silica and asbestos for all temperatures to 1900F

YOU'LL ENJOY *greater insulation savings* with Superex®. Its unique combination of low conductivity and outstanding resistance to high temperatures provides greater operating efficiency and longer maintenance-free service. That's why Superex is the leading block insulation for furnace work.

Light and easy to work. Superex withstands temperatures to 1900F indefinitely with negligible loss of efficiency and is so strong that it compresses only ⅛ inch under 6 tons' pressure per square foot. Its light weight, excellent working properties and availability in large blocks mean quick, easy, low-cost installation.

For high temperature equipment. Since its introduction in 1927, Superex has received enthusiastic acceptance. Today it economically insulates 90% of the country's hot blast stoves. Other high temperature equipment where Superex has proved its superior performance include most types of industrial and metallurgical furnaces and ovens, stationary and marine boilers, regenerators, kilns, roasters, high-temperature mains, flues and stacks.



Saves waste—Superex comes in 7 standard thicknesses from 1" to 4". Other sizes available on order.

For further information on Superex, write to Johns-Manville, Box 60, New York 16, N. Y. In Canada, Port Credit, Ont.

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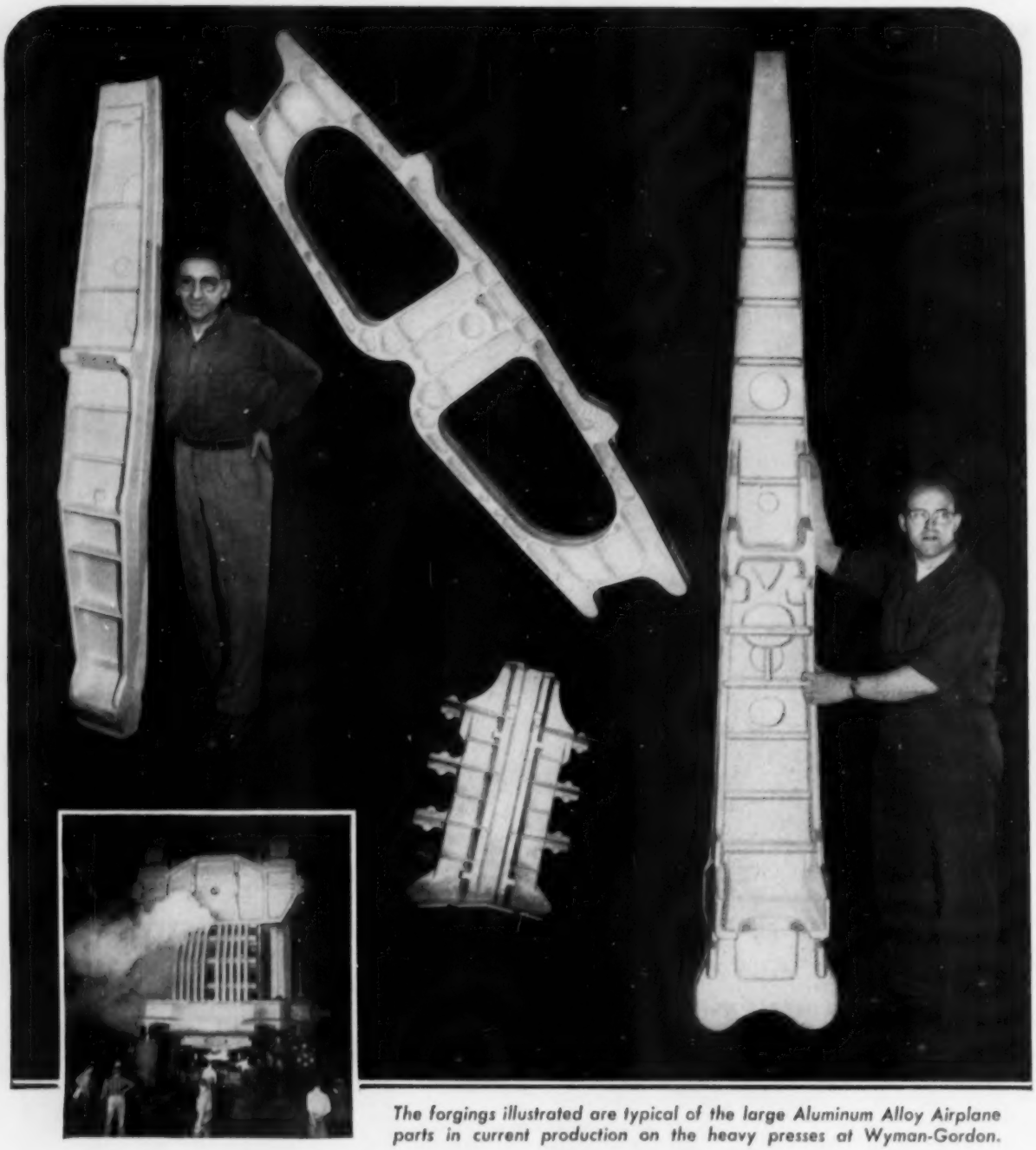

The forgings illustrated are typical of the large Aluminum Alloy Airplane parts in current production on the heavy presses at Wyman-Gordon.

A new era in the art of forging has been demonstrated as production goes forward on this 35,000-ton closed die forging press. Larger forgings with thinner sections and closer tolerances than heretofore possible open new concepts in forging design. Wyman-Gordon continues to pioneer by — Keeping Ahead of Progress.

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Established 1883

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STEEL • TITANIUM

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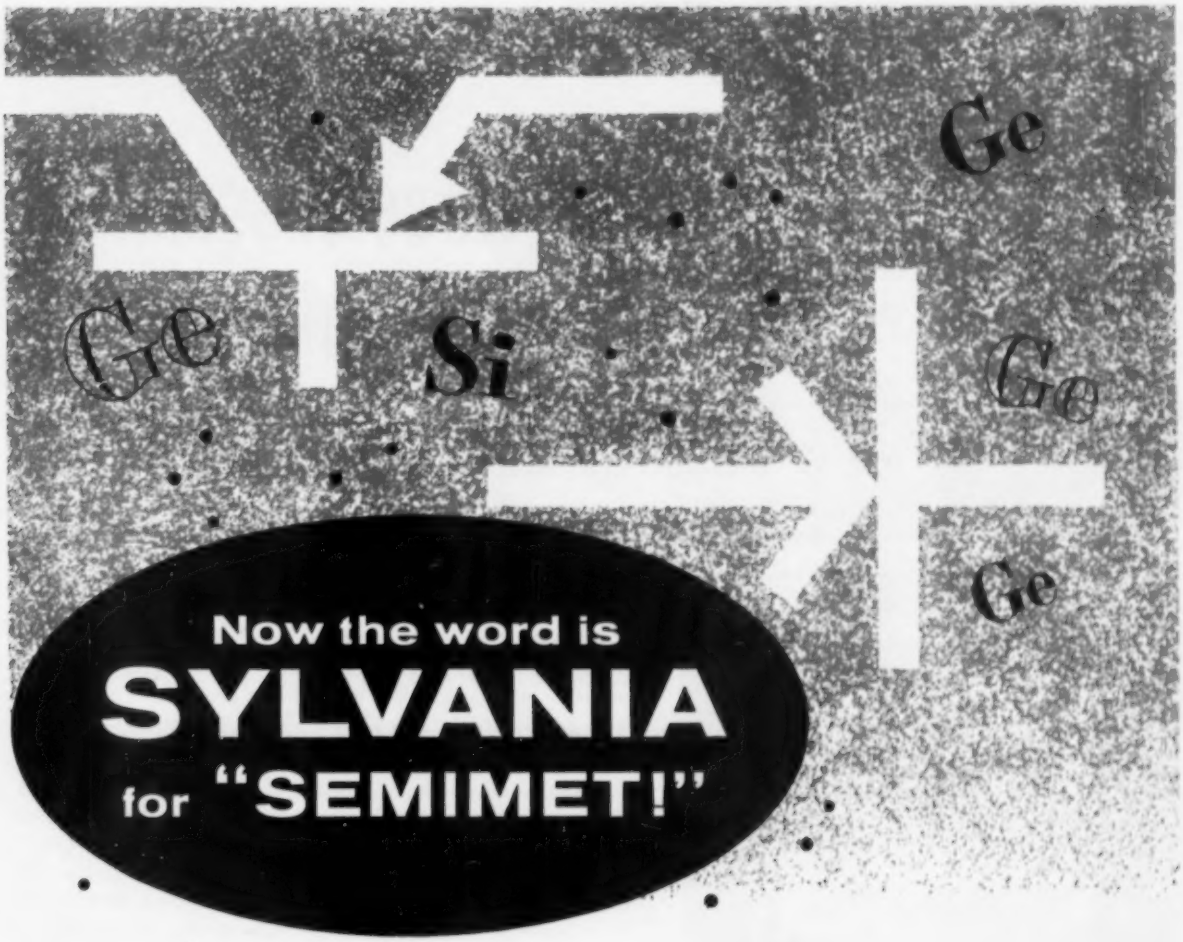

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...your single source for both transistor-grade silicon and germanium

Sylvania has long been a primary refiner of high-purity germanium. Now, newly completed facilities for the production of high purity silicon are operating on a pilot plant basis, producing the semimetal in needle or densified form, of spectrographic purity. Full production is expected in the spring. At present, transistor-grade samples are available for your testing on a letterhead request basis.

Specifications for Sylvania germanium dioxide and semimetal include ingot as-reduced (guaranteed 5 ohm cm resistivity) and polycrystalline ingot (guaranteed minimum 30 ohm cm resistivity). Whichever grade you prefer, you can be sure of continuing high quality and uniformity when you order from Sylvania.

If you use semimetals in your products . . . or plan to in the future . . . write for technical specifications and quotations on Sylvania silicon and germanium. Remember, too, that our engineering staff is always ready to help you solve semimetal application problems.

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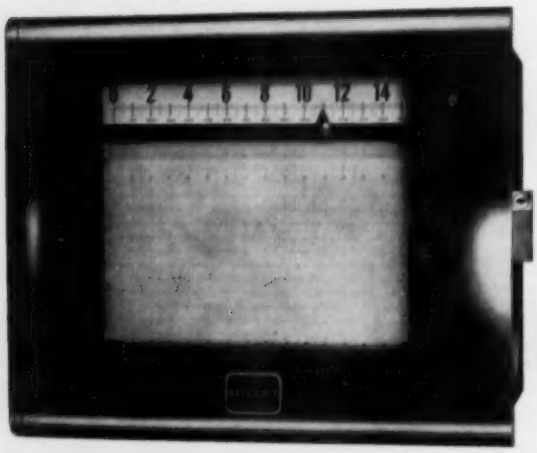
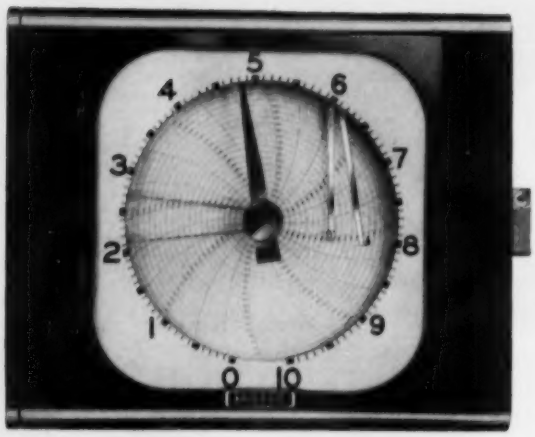
WHAT'S NEWS AT BRISTOL . . .



Three reasons temperature control is better with Bristol



FIRST TWO REASONS are Bristol's Electronic Dynamaster Potentiometers with strip chart or round chart. Here's why:

No-Batt Continuous Standardization in these instruments eliminates need for dry cells. Result: No interruption in operation for standardization, no batteries to replace.

Recorders for every requirement – single-pen, two-pen, and multiple-record (up to 24 points)

Electric and pneumatic controllers for every furnace and oven control mode, including *electric controllers* for on-off, proportional-input, 3-position, proportional, proportional plus automatic reset, and time-program control; and *pneumatic controllers* for on-off, proportional, proportional plus reset, and proportional plus reset plus derivative control.

THIRD REASON: Bristol's Free-Vane® Electronic Pyrometer Controller. No relay chatter with this controller! Bristol's thyratron-operated relay puts a stop to that. Minute changes in temperature – less than 0.003" on scale – close or open the relay with positive trigger action. Available in thermocouple and radiation pyrometer controllers in ranges up to 4000F. New high-torque, rugged millivoltmeter gives greater accuracy and a sensitivity of 15 ohms per millivolt. Separate plug-in control units, variety of control modes available.

Get the whole story on these three rugged Bristol Furnace and Oven Controls. Write for free 48-page Bulletin P1260 today. It contains specifications, control diagrams and prices for every type of automatic heating control. The Bristol Company, 106 Bristol Road, Waterbury 20, Conn.

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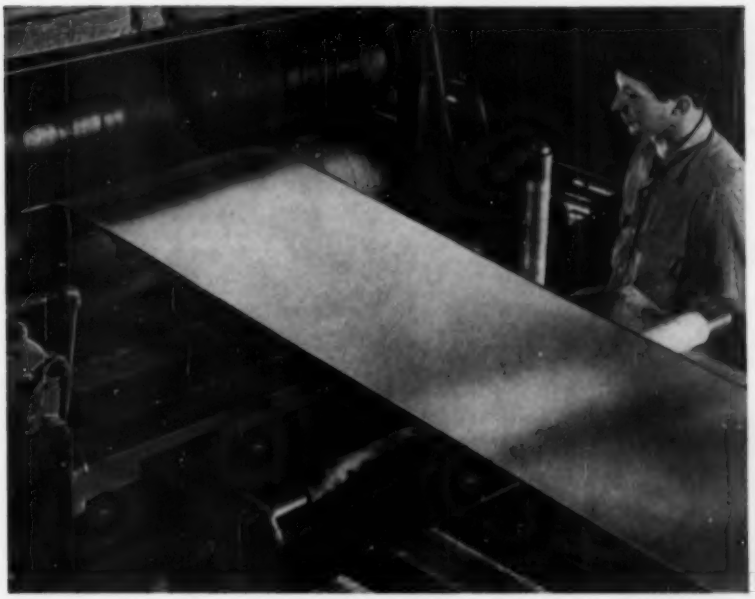
BRISTOL'S

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS



TITANIUM STRIP is descaled continuously on time cycles as low as 30 seconds, with excellent results.

10-MINUTE IMMERSION loosens scale on 5 tons of stainless wire. A water quench, 3-minute acid dip, and final water rinse produce a clean, bright surface with no pitting or etching.

Use this fast, safe Hooker Process for descaling steel and titanium

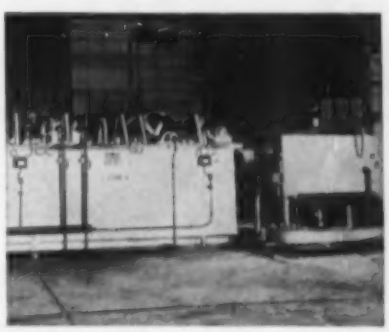
Descale alloy steels and titanium in any form—rapidly, safely—using the Hooker Process with Virgo® Descaling Salt.

A bath of molten Virgo Descaling Salt quickly converts scale, rust, and other surface impurities to an acid-soluble coating. A quench, acid dip, and final spraying then remove this coating in from one-tenth to one-hundredth the usual pickling time, with no measurable effect on the base metal.

You can easily set up the Hooker Process for batch or continuous operation on any form of work including strip, sheets, bars, wire, tubes, plate, castings, forgings, and fabricated parts. You can usually process work as fast as your handling methods allow, with a minimum of supervision. Operation is safe for personnel, and there is little or no spent-acid disposal problem.

You can profit by the experience of more than 50 companies now using the Hooker Process successfully to speed up descaling of alloy steels and titanium in practically every form.

You'll get quick service on any descaling problem, by writing or phoning us. Complete test and engineering facilities are at your disposal, without obligation.



LIGHT-GAUGE ALLOY STRIP is descaled at 20-35 ft. per min. in this Virgo bath, after annealing.

Send for these bulletins—Get the whole story on Virgo Descaling Salt for alloy steels and titanium . . . how the Hooker Process works, its advantages, how to set up a Virgo descaling line, and the services you enjoy as a user. No obligation. Write us today.

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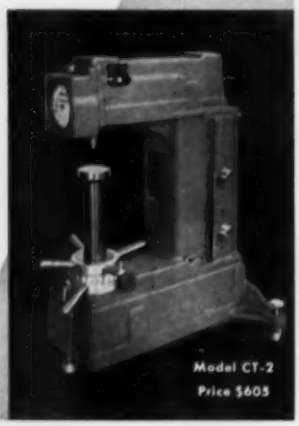
Want complete information? Write for Bulletin RS.



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Price $605

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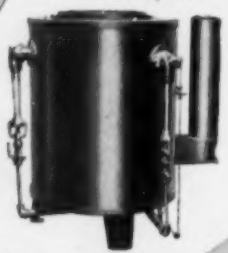

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BRASS & BRONZE
Think of Sonken Galamba

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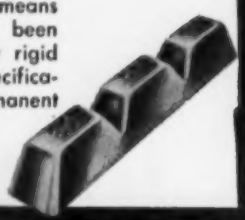

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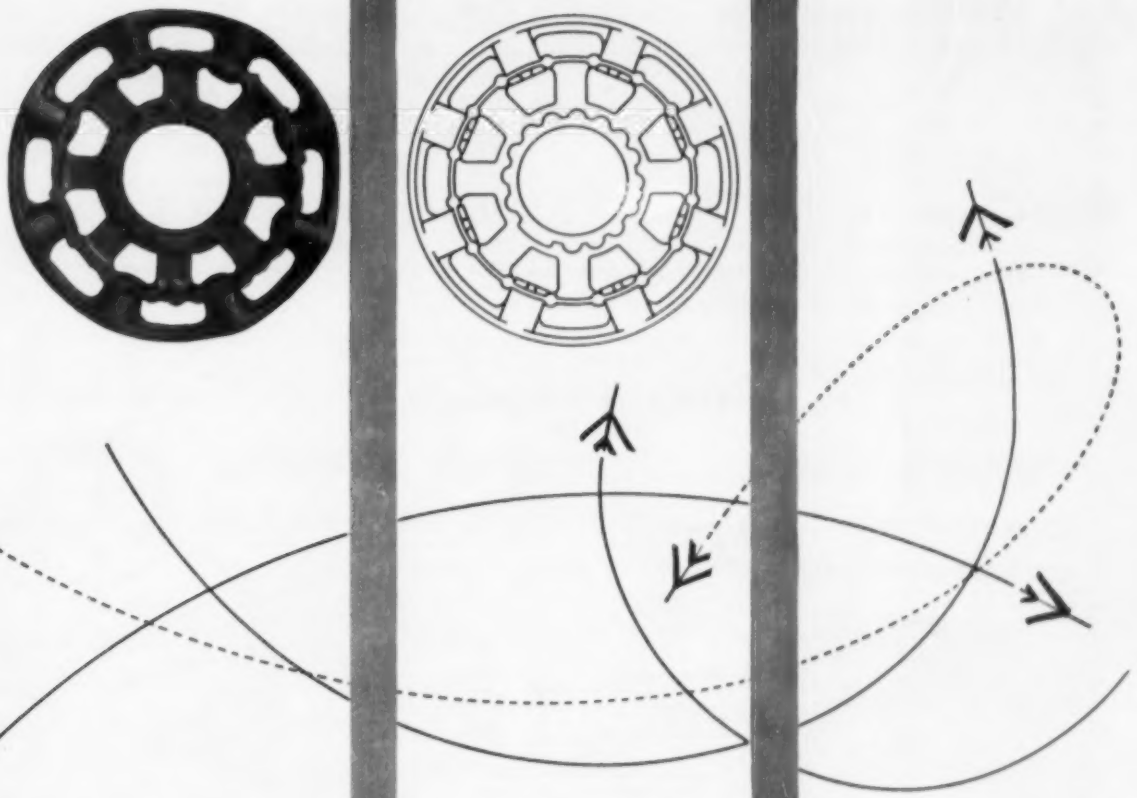

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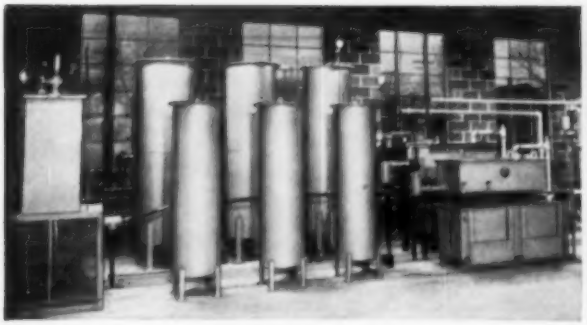
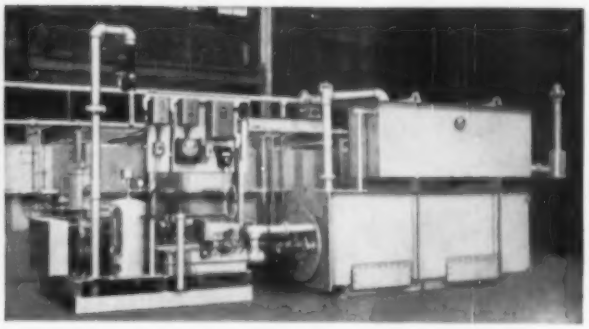


An EF installation consisting of a 1500 and a 3000 cfh exothermic horizontal water cooled type special atmosphere unit, each with desulphurizing towers and refrigerators for bright annealing steel and copper, and clean annealing brass.



An EF kerosene exothermic gas generator. These are also built in several sizes and types for producing special atmospheres for use in bright annealing copper and steel products in areas where fuel gases are not available.

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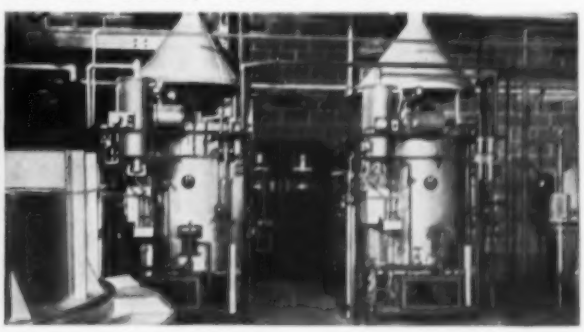
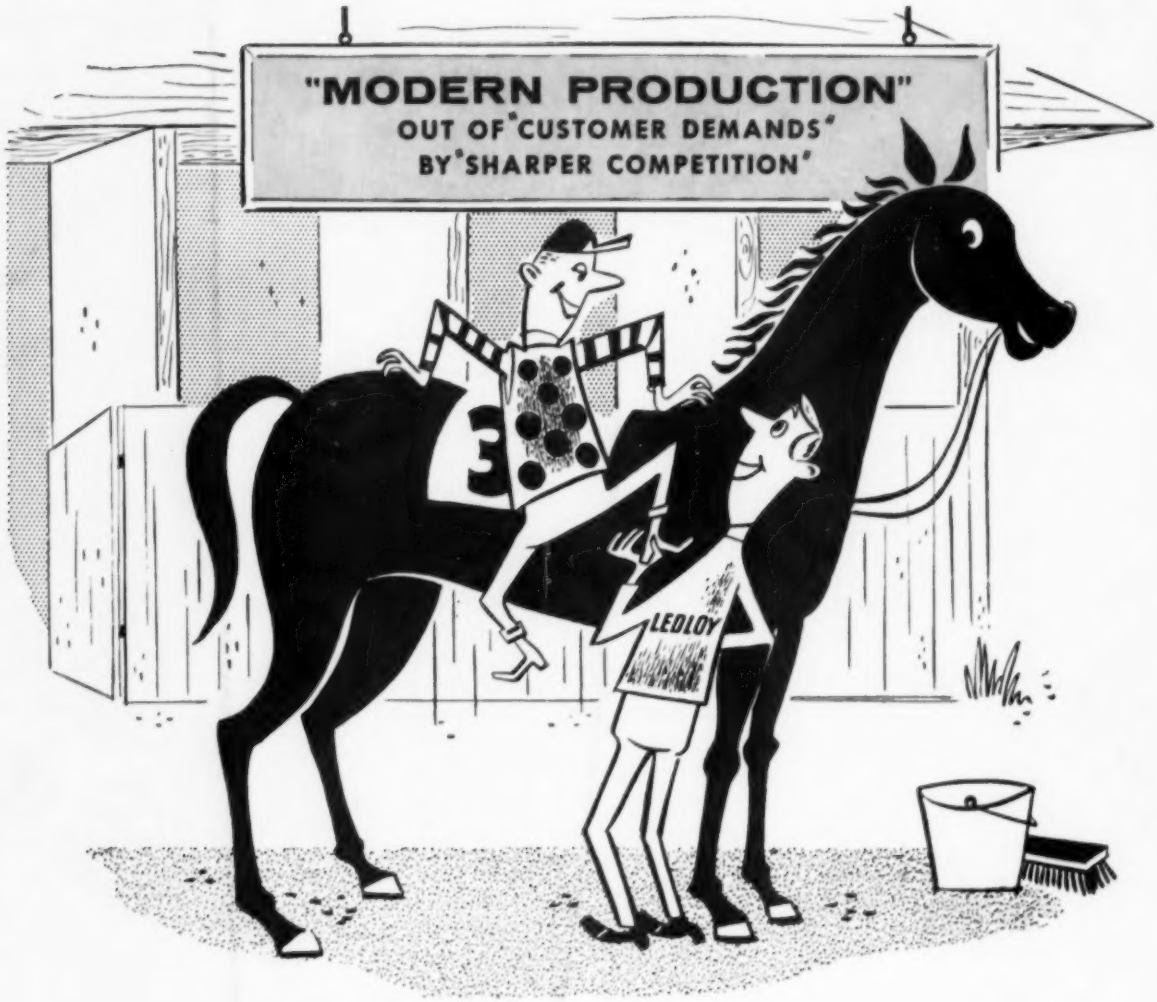


An installation consisting of two small EF oil fired endothermic generators producing special atmospheres from propane for carburizing and other processes.



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